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## PATHOLOGIC CLASSIFICATION, WITH SURGICAL CONSIDERATION, OF INTRASPINAL TUMORS\*

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A REVIEW of a large series of intraspinal lesions for which operations were performed at the Mayo Clinic reveals a preponderance of benign tumors which were operable. The earlier intraspinal tumors are recognized, the less will be the damaging effects on the spinal cord and the more complete will be the recovery of the patient when the pressure has been relieved by the removal of the tumor.

The factors responsible for the development of tumors of the meninges, nerve roots, blood vessels and the spinal cord are similar to those responsible for the development of tumors elsewhere. They occur most frequently in the third, fourth and fifth decades of life, but may occur among children or among elderly patients.<sup>24</sup> Trauma may be a predisposing factor to the development of osteomata, sarcomata, foreign body giant cell tumors and fibromata. Trauma is also responsible for the rupture of the intervertebral disks with protrusion of the nucleus pulposus into the spinal canal. Although the lesion under consideration may produce symptoms similar to those of caudal tumors, it is not a true neoplasm. Trauma and chronic infection may give rise to hypertrophic arthritis and osteitis, both of which are capable of producing radiculitis and slowly progressive myelitis simulating the symptoms of intraspinal tumor. Primary malignant tumors of the osseous system, as well as metastatic lesions, are rarely considered surgical lesions, although a number of patients having such tumors have been surgically explored when it was not possible to make a preoperative differential diagnosis. Hemangioma of the vertebrae, Paget's disease of the spinal column and Potts' disease of the vertebrae frequently produce involvement of the nerve roots and spinal cord, but are rarely benefited by surgical intervention.

*Symptoms.*—Tumors which arise from the tissues surrounding the spinal cord have been designated as "extramedullary," in contrast to those which arise in the cord itself, which have been called "intramedullary." Oppenheim

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and Frazier have divided the symptoms of extramedullary tumors into three phases. The first phase is that of involvement of nerve roots;<sup>31</sup> the second, that of beginning compression of the spinal cord; and the third, that of extreme compression of the spinal cord, producing the clinical picture of transverse section of the cord.

The outstanding symptom of involvement of nerve roots is pain, which is usually characteristic and pathognomonic.<sup>18</sup> It may precede any other symptoms by months or years; it may be constant or intermittent, persist in a localized region, and radiate over the involved nerves. It is usually lancinating, and is aggravated by coughing, sneezing, lifting and straining at stool, and it invariably awakens the patient from four to six hours after he has retired. It often becomes so severe as to compel him to walk the floor or to sleep in a sitting position. The mechanism that produces this pain apparently is the ball-valve action of the tumor, which is forced downward by the increased pressure of cerebrospinal fluid above it, thus producing traction directly or indirectly on the nerve roots. Unfortunately, many of the patients are treated for neuritis, muscular rheumatism, or syphilis, and some have been thought to have had hysteria. The importance of recognizing or suspecting the first, or painful, phase in the development of tumors of the spinal cord was emphasized in a recent survey by Craig,<sup>13</sup> in which 10 per cent of the patients who had root pain had been operated upon for some thoracic or abdominal lesion other than an intraspinal tumor.

The symptoms which develop in the second symptomatologic phase, the phase of beginning compression of the spinal cord, differ from those of the first phase in that neurologic evidence of compression of the cord now becomes evident. The symptoms may develop simultaneously with the existence of pain,<sup>13</sup> or they may develop without pain in a small percentage of cases. If the tumor is situated anterolaterally, the symptoms will progress and produce the Brown-Séquard syndrome, a homolateral paralysis of the muscles below the level of the lesion, with impairment of tactile and deep sensibilities on the same side, together with loss or diminution of pain and temperature on the opposite side. If the posterior columns of the cord are the first to be compressed by the tumor, the deep sensibility is decreased and ataxia appears. Sensory disturbances resulting from compression of the cord are gradual in onset, and progress upward to a transverse level corresponding to the segment of the cord that is compressed. At the lower end of the spinal cord other difficulties may be encountered. The relative shortening of the cord incident to growth, and the emergence of the roots through the anterior foramina of the sacrum often make it extremely difficult to determine whether there is a tumor of the conus medullaris, of the cauda equina, or of the sacrum. The objective findings may be the same. In this group studies with radiopaque oil are valuable in localizing and differentiating the lesion. Paralysis below the level of the tumor comprises the third symptomatologic phase, and is caused by extreme compression of the cord.<sup>12</sup> The paralysis is usually complete, sensory functions are entirely lost, trophic disturbances are present, and there is definite loss of control of both vesical and rectal sphincters.

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Intramedullary tumors rarely produce pain, but pass directly into the second symptomatologic phase. The sensory and motor disturbances are progressive until a definite transverse level becomes evident. The upper sensory level is less distinct than that produced by extramedullary tumors. Increased reflexes and loss of vesical and rectal control appear early in the symptom-complex.<sup>1, 14</sup>

*Examination.*—The symptoms which play important parts in the diagnosis of intraspinal lesions emphasize the necessity of a comprehensive history in all cases. Following the taking and recording of the history, a detailed general, as well as a neurologic, examination is necessary. These examinations should include such special features as spinal puncture, Queckenstedt studies, and roentgenograms of the spinal column, with or without the introduction of iodized oil.

*Neurologic Examination.*--In the case in which tumor of the spinal cord is suspected there is no investigation so important as complete neurologic examination. The information elicited by a detailed testing of reflexes, muscular strength, muscular tonus, sensory acuity, gait, coordination, and balance tends to distinguish between degenerative diseases and compression of the cord.

*Spinal Puncture.*—This examination is very important, because it reveals information concerning the physical properties and the hydrodynamic properties of the spinal fluid,<sup>8</sup> and allows its chemical reactions to be determined.<sup>2</sup> The puncture is usually performed at the fourth lumbar interspace, and before any fluid is removed the intraspinal pressure is estimated by means of Ayer's water manometer, which normally registers between 12 and 15 cm. As soon as the pressure has been estimated, Queckenstedt's test is made. This consists of reading and studying the rate of rise of the cerebrospinal fluid in the manometer following compression of both internal jugular veins. Sudden rise and rapid fall of the fluid on compression of both internal jugular veins indicate free flow of cerebrospinal fluid within the subarachnoid space. Slow rise and fall of fluid or its failure to rise on compression of the jugular veins suggests partial or complete intraspinal block.

Inability to obtain fluid at the fourth lumbar interspace may signify that the tip of the needle has failed to enter the subarachnoid space, that fluid is absent, or that there is a tumor at this level. Puncture should be made at another level, and it may be necessary to make multiple punctures. Occasionally, it is necessary to combine cisternal puncture with lumbar puncture.

Spinal block, if it results from tumor, frequently causes an increase in the concentration of globulin in the cerebrospinal fluid below the tumor. The fluid may also be xanthochromic<sup>17</sup> (Froin's syndrome<sup>21</sup>). The shade of yellow may vary, and occasionally the fluid above a block is decidedly yellow. The cell count is usually normal, but pleocytosis may occur if the tumor is situated in the spinal canal below the conus medullaris. This may help in distinguishing neoplasms from inflammatory lesions.

The presence of partial or total subarachnoid block is not pathognomonic of intraspinal tumor, since previous attacks of meningitis, acute myelitis, injuries to the vertebrae, or spinal deformities are all capable of interfering

with the free flow of cerebrospinal fluid. It is, however, apparent that the finding of partial or total block is extremely valuable in diagnosis when the block is accompanied by a history of root pain, and with a negative history of inflammation or trauma of the spinal cord.

*Roentgenographic Examination.*—Roentgenograms should be made of anteroposterior and lateral aspects of the vertebral column.<sup>22</sup> These should be supplemented by stereoscopic and oblique views, localized at the level where, on clinical grounds, a tumor has been suspected. According to Camp and Adson,<sup>10</sup> evidence of erosion of the vertebral pedicles, laminae, and lateral and spinous processes caused by pressure usually is discernible before such erosion is evident in the body of the vertebrae. In general, roentgenologic evidence of changes resulting from tumors of the spinal cord consists of shadows indicative of erosion secondary to direct pressure, invasion by the tumor,

LOCATION OF 557 CLASSIFIED INTRASPINAL NEOPLASMS  
TO JAN. 1, 1939

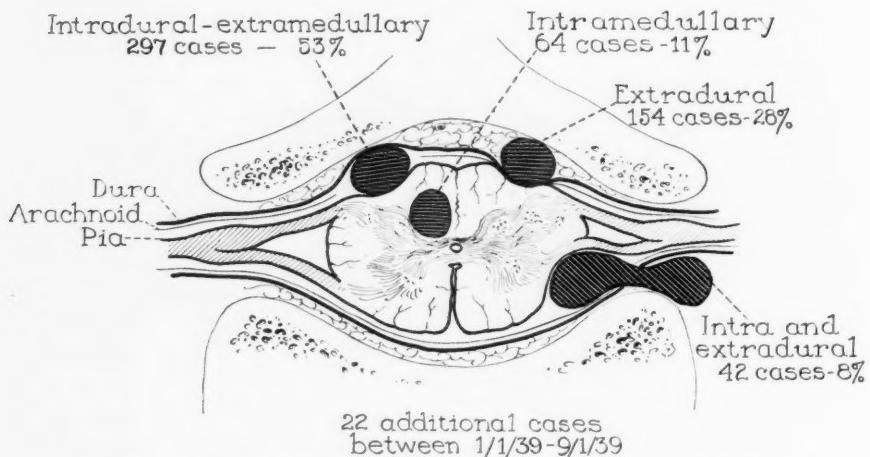


FIG. 1.—Location of 557 classified intraspinal neoplasms, to January 1, 1939.

destruction caused by benign or malignant tumor of the bone, metastatic diseases and hyperostosis.<sup>9</sup>

*“Study with Radiopaque Oil.”*—In addition to the roentgenologic evidence of tumors which is apparent in routine examination of the spinal column, fluoroscopic and roentgenographic study by the use of radiopaque oil has furnished much additional information in diagnosis and localization of intraspinal tumors. Injection of 5 cc. of iodized oil into the subarachnoid space, either through cisternal puncture or lumbar puncture, allows visualization under the fluoroscope of the patency or lack of patency of the subarachnoid space. Fluoroscopic examination of the slowly moving oil is superior to examination of a roentgenogram, since the roentgenologist often sees the diversion of the current of oil around the tumor. However, roentgenograms should be made for confirmation of the levels where tumors are suspected to be. Intramedullary tumors are identified by division of the oil into two currents, one on each

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side of the cord. Use of the heavier oils avoids their ascent into the cisterns and ventricles. Because introduction of these oils invariably produces irritation of the meninges, and occasionally radiculitis, they should be used only to localize tumors definitely. After the oil has been injected, the patient should

### CLASSIFICATION OF 557 INTRASPINAL NEOPLASMS

**Neurofibromas - 163 cases - 29%**

**Meningiomas - 140 cases - 25%**

**Intramedullary tumors - 64 cases - 11.5%**

**Sarcomas, etc. - 55 cases - 10%**

**Extramedullary hemangioendotheliomas, etc. - 47 cases - 8.5%**

**Extramedullary ependymomas (filum) - 32 cases - 6%**

**Chordomas - 23 cases - 4%**

**Miscellaneous extramedullary tumors - 33 cases - 6%**

FIG. 2.—Classification of 557 intraspinal neoplasms.

be placed prone on the fluoroscopic table, and the flow of oil should be observed when he is tilted in various positions, from horizontal to perpendicular. Experience with the use of radiopaque oil in the diagnosis of tumor of the spinal cord has indicated that oil should be used infrequently, only when tumors are suspected, and that the oil should be removed at operation whenever possible. The presence of extramedullary tumors usually is indicated by definite arrest of the flow of lipiodol. If there is no tumor or compression of the cord the oil descends and remains permanently in the sacral cul-de-sac.<sup>32</sup>

**Pathologic Considerations.**—Up to January 1, 1939, there had been performed at the Mayo Clinic operations for 557 verified intraspinal neoplasms (Fig. 1). These lesions have been classified pathologically and grouped according to situation (Figs. 2 and 3). It is apparent that the distribution of

### GENERAL DISTRIBUTION OF 557 CLASSIFIED INTRASPINAL NEOPLASMS

**Cervical - 100 cases - 18%**

**Thoracic - 304 cases - 54%**

**Lumbar - 117 cases - 21%**

**Sacral - 35 cases - 7%**

**Multiple levels - 1 case**

FIG. 3.—General distribution of 557 classified intraspinal neoplasms.

these tumors with reference to the spinal axis has no predilection for any one region.

*Neurofibromata* constitute the largest single group (Fig. 4). *Meningioma* compose the second largest group, and their primary distribution in the thoracic region is shown in Figure 5. *Intramedullary Tumors*: The various

#### LOCATION AND DISTRIBUTION OF 163 NEUROFIBROMAS

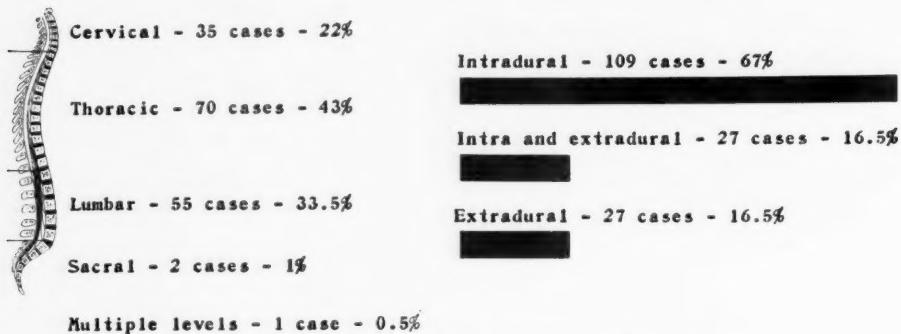


FIG. 4.—Location and distribution of 163 neurofibromata.

#### LOCATION AND DISTRIBUTION OF 140 MENINGIOMAS

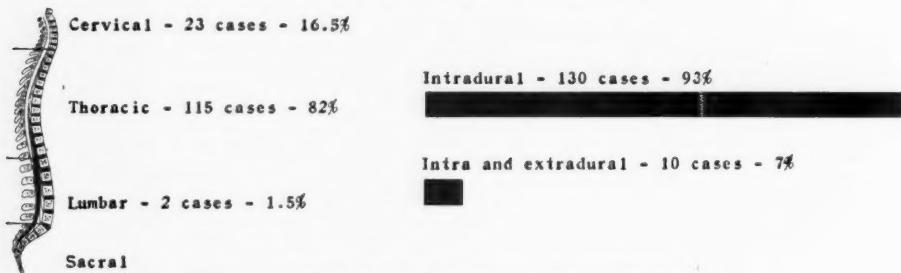


FIG. 5.—Location and distribution of 140 meningiomas.

types of tumors represented in the group of 64 classified intramedullary tumors<sup>5</sup> are best illustrated by referring to Table I, and their situation is illus-

trated in Figure 6. The *ependymomata* are fairly evenly distributed throughout the spinal cord (Fig. 7). Half of them arise from the spinal cord proper and the remaining half from the filum terminale.<sup>6</sup> *Vascular tumors* form a group including the hemangio-endotheliomata and hemangioma, and their distribution and situation are illustrated in Figure 8.<sup>4, 10</sup> *Chordomata*, as previously stated, may be situated in any portion of the spinal column, but they have a predilection for the sacral region (Fig. 9). *Sarcomata*, under the heading "sarcomas," are included in a miscellaneous group of 55 sarcomatous

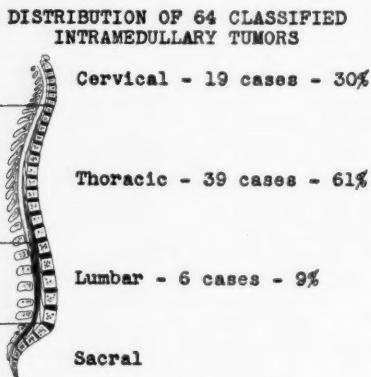


FIG. 6.—Distribution of 64 classified intra-medullary tumors.

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lesions consisting of lymphosarcomata, myelosarcomata, giant cell sarcomata, Hodgkin's disease, osteogenic sarcomata, etc. Eleven per cent are situated in the cervical region, 56 per cent in the thoracic region, 22 per cent in the lumbar region, and 11 per cent in the sacral region. Ninety-one per cent

## LOCATION AND DISTRIBUTION OF 65 EPENDYMONAS

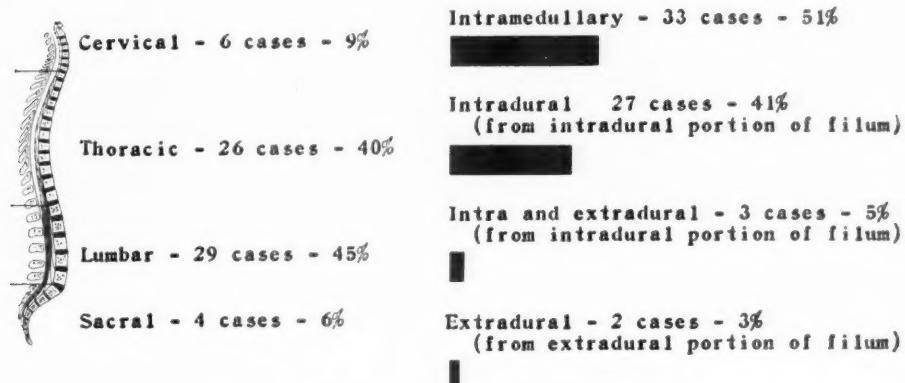


FIG. 7.—Location and distribution of 65 ependymomata.

## LOCATION AND DISTRIBUTION OF 52 BLOOD VESSEL TUMORS

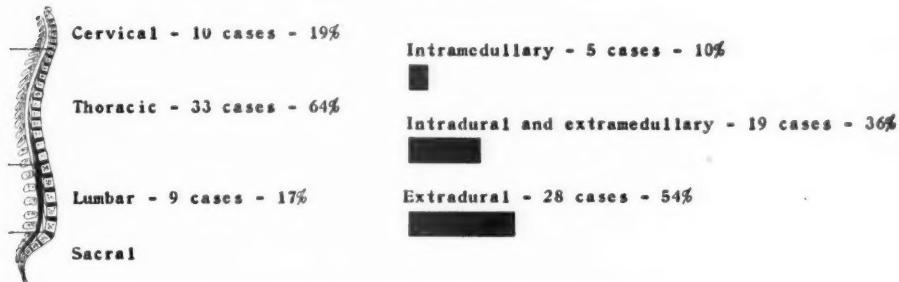


FIG. 8.—Location and distribution of 52 blood vessel tumors.

TABLE I  
CLASSIFICATION OF 64 INTRAMEDULLARY NEOPLASMS

Tumor	Number	Per Cent
Ependymoma and ependymoblastoma.....	33	51.0
Astrocytoma and spongioblastoma polare.....	10	15.5
Oligodendrolioma and oligodendroblastoma.....	3	5.0
Spongioblastoma multiforme.....	3	5.0
Medulloblastoma.....	3	5.0
Ganglioneuroma and neuroblastoma.....	2	3.0
Hemangio-endothelioma, etc.....	5	7.5
Melano-epithelioma.....	3	5.0
Fibrolipoma.....	1	1.5
Neurofibroma.....	1	1.5
Total.....	64	100.0

were situated extradurally, 5 per cent were intradural and extradural, and 4 per cent were intradural and extramedullary.

*Miscellaneous Extramedullary Tumors.*—Included in this group were six astrocytomata, one spongioblastoma multiforme, two ganglioneuromata,<sup>25</sup> six chondromata, two osteomata, three lipomata, two fibromata, two dermoids and one teratoma.

#### LOCATION AND DISTRIBUTION OF 23 CHORDOMAS

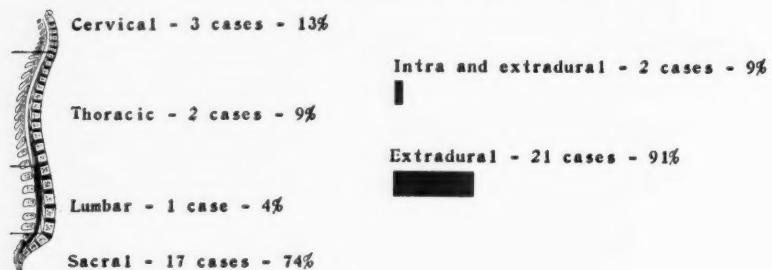


FIG. 9.—Location and distribution of 23 chordomata.

#### LOCATION OF 377 NON-NEOPLASTIC INTRASPINAL MASS LESIONS TO JAN 1, 1939

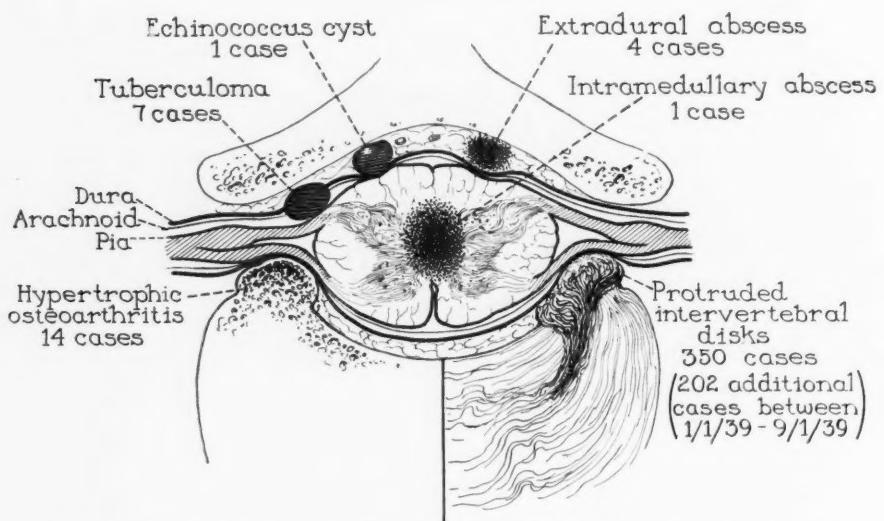


FIG. 10.—Location of 377 nonneoplastic intraspinal mass lesions, to January 1, 1939.

In addition to the described verified intraspinal tumors, there were 468 additional intraspinal lesions which produced irritation or compression on the nerve roots or the spinal cord, suggesting, clinically, the possible existence of an intraspinal tumor or compression of the nerve roots and spinal cord by a nonneoplastic lesion (Fig. 10). Of the 468 lesions there were 64 intramedullary lesions, presumably tumors or cysts of the spinal cord, which were not identified by biopsy. There were 29 additional, unclassified lesions situated within the spinal canal. The tissue removed to date has not been pathologi-

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cally classified. In this same group of 468 cases, there were 377 nonneoplastic lesions, which includes protruded intervertebral disks, osseous compression of the roots and spinal cord and suppurative lesions (abscesses) within the spinal canal.<sup>15, 34</sup>

*Surgical Consideration.*—The technic of a laminectomy has become standardized and, therefore, a detailed description is unnecessary.<sup>20</sup> The anesthetic method we have found most suitable, after employing a variety of them, is that in which the ether is dropped onto an open mask which is held over a Magill intratracheal tube. The intratracheal tube is introduced as soon as the patient has been anesthetized with nitrous oxide and ether. In proceeding with a laminectomy one should make sure of the localization of the lesion, and bear in mind that unless the lesion has been localized by a roentgenogram the cord levels are situated above the corresponding osseous segments. A subperiosteal elevation of the periosteum and muscles will result in less bleeding than a lateral reflection of the erector spinae muscles by sharp dissection. Extreme care should be taken in removing the laminae from the tumor, in order to avoid additional trauma to the cord. The surgeon should also have in mind that dural pulsations will be detected above the tumor but will be absent below it, since this observation will direct him in extending the laminectomy in the proper direction in order to expose and remove the growth properly. Laminectomies performed in the thoracic and lumbar regions usually consist of removing both laminae and the spinous processes of from two to three vertebrae. However, it frequently becomes necessary to extend the laminectomy for longer distances when removing ependymomata of the filum terminale or neurofibromata of the caudal fibers. The tips of the spines, in immediate approximation above and below the site of laminectomy, are also removed in order to eliminate any bony prominences.

Hemilaminectomy is definitely indicated in removing lesions of the cervical portion of the cord, since bilateral laminectomy with removal of the spines may give rise to a slipping forward of the cervical vertebrae, one upon the other, and the entire cervical group upon the first thoracic vertebra. When it does become necessary to perform bilateral cervical laminectomy, extreme care should be exercised in closing the incision so that the cut edges of the ligamentum nuchae will be accurately approximated. When slipping occurs, the patient will exhibit progressive signs of a lesion of the transverse portion of the cord. Lateral roentgenograms will quickly confirm the suspicion. It then becomes necessary to place the patient in bed on his back with extension applied to the head. As soon as the symptoms subside, a cancellous bone graft taken from the crest of the ilium should be inserted along the freshened bone edges of a previous laminectomy.<sup>3</sup> The graft should be extended for a distance of one to two laminae above and below the site of the former laminectomy. Grafts should be placed well laterally to avoid pressure on the spinal cord. In a few instances in which the laminectomy has included the atlas and axis, the graft is brought in contact with the occipital bone. This same procedure has been employed to relieve the pressure on the upper

part of the cervical portion of the cord when an anterior slipping of the atlas on the axis has taken place following fracture or destruction of the odontoid process of the axis.

*Neurofibromata.*—Since neurofibromata may arise from the nerve roots within the dura, from the roots as they penetrate the dura, or from the peripheral nerve just lateral to the dura, it will be found that these lesions may be situated wholly within the spinal canal, intradurally or partly within the dura, and partly outside of the dura, or they may be situated extradurally with an enlargement and a protrusion into the intervertebral foramen, or they may present the typical dumb-bell appearance, with one portion within the spinal canal just described, with a similar projection beyond the intervertebral foramen. Neurofibromata situated in the spinal canal, even though they have eroded the bone around the intervertebral foramen, usually can be removed during a one-stage operation. Those which are dumb-bell tumors and are situated in the cervical region of the canal are more effectively removed through two separate incisions, and the extraspinal portion of such a tumor is removed first through a lateral cervical incision. This incision is closed and is then followed by laminectomy, frequently hemilaminectomy, through which the intraspinal portion is removed.

Many of these so-called dumb-bell tumors involve the thoracic nerves, and the extraspinal projection may vary in size from a small nodule to a tremendous mass the size of a baby's head.<sup>29</sup> It is not infrequent for the thoracic portion not only to erode the bone around the intervertebral foramen, but also to erode the pedicles, transverse processes of the vertebrae, and portions of ribs. The erosion produced by a neurofibroma is similar to that produced by a meningioma, since it results in smooth erosion and not in the irregular, ragged type of destruction so characteristically produced by metastatic tumors.<sup>11</sup> When a malignant change takes place in a neurofibroma, the bony invasion and destruction resembles that of a primary malignant lesion, and recurrence is almost sure to take place even though a radical removal has been performed.

Since both laminectomy and thoracotomy are major operations, it has been our practice to perform laminectomy and remove the intraspinal portion of the tumor first and wait for the patient thoroughly to convalesce from the first operation before performing the second. This period of waiting usually extends over a month or two. There is one precaution that the thoracic surgeon has to consider and that is to effect complete hemostasis following the removal of the intrathoracic portion of the neurofibroma. Moreover, he must be especially cautious not to apply forceps or to introduce packs along the spinal column where the defect exists, a procedure which might cause trauma to the cord. We have found it advantageous at the Clinic for both the neurologic and thoracic surgeons to assume joint responsibility<sup>16</sup> in order that one may understand the objectives of the other and observe what has been done so that the strength of the patient may be evaluated before the second stage of the operation is begun.

Most neurofibromata within the spinal canal have a tendency to degenerate and become cystic, and in a number of instances, in the lumbar region, the neurofibromata have been known to grow to considerable size, eroding laminae, pedicles and bodies of the vertebrae without producing signs of complete paraplegia. On visualizing these cystic tumors, it is observed that the dura and extradural fat have become atrophic, that the lining of the cyst and the dura are almost inseparable, and that a puncture of the cyst has resulted in escape of the yellow fluid and collapse of the wall of the tumor, making it rather difficult for the surgeon to identify the lesion; but, on further observation, it is usually found that the root is involved and also the remaining nubbin of tumorous tissue. Neurofibromata involving the roots of the spinal cord are usually singular, but occasionally may be multiple and may be part of von Recklinghausen's disease.

*Meningioma.*—Meningioma, fibroblastomata originating from the arachnoid, may be situated in any portion of the spinal canal and be located in any part of the circumference of the canal about the cord, producing pressure at the point of origin. The most common site of origin of such a lesion is about a nerve root, but not originating from it. The meningeal attachment is usually rather limited, although the tumor may grow in all directions without becoming attached to the cord. Occasionally, the meningioma is sessile in type, instead of being rounded or oval in shape. When the tumor is sessile, it involves a large portion of the dura surrounding the cord. Usually it is possible to remove the tumor mass *in toto*, but in doing so it is necessary to remove a portion of the arachnoid and dura, since they are intimately attached at the site of origin. If the surgeon fails to do this, recurrence will develop. Hemostasis is most effectively accomplished during the removal of the tumor by applying electrocoagulation to the base of the tumor extradurally. Care must be taken not to overheat the tumor, since this could result in impairment of the circulation of the cord. In a few instances, in which the tumor is situated anterior to the cord, it may become necessary to remove the tumor by the piecemeal method in order to avoid undue traction or pressure on the spinal cord.

Following the removal of meningioma and neurofibromata, the surgeon frequently observes marked indentations of the cord. These indentations may have compressed the cord to less than half its normal size, but we have also observed that even though the indentation has markedly flattened the cord, complete recovery of the patient will take place if the blood supply of the cord has not been destroyed.<sup>7</sup> The gradual growth of the tumor will have produced destruction and absorption of the myelin before destruction of the axis cylinder, results which explain why recovery takes place. As a rule, it is not necessary to attempt repair of dural defects resulting from the necessary removal of small portions of the dura with the attached tumor, if the surgeon is careful to maintain absolute hemostasis. We frequently cover the defect with a portion of animal membrane (prepared peritoneum of the ox) to prevent the entrance of blood into the arachnoid or subdural spaces.

This same rule applies to dural defects resulting from the removal of other tumors that are adherent to the dura.

*Intramedullary Tumors.*—The surgical consideration of intramedullary tumors is almost the same for the entire group of lesions, even though they may vary in their pathologic classification. Most of them are gliomatous in origin. The largest group is the ependymomata. These tumors originate from the ependymal cells lining the central canal. Several hemangio-endotheliomata have been found to be situated within the cord; one large intramedullary lipoma and one neurofibroma were found to have invaded the cord for an unusually long distance. Unless cystic degeneration has taken place in or about the tumor, the surgical approach is the same for all intramedullary tumors. Cysts are readily emptied, as is also the cystic cavity of a syringomyelia, and occasionally the surgeon is able to maintain constant drainage or prevention of filling by resection of the wall of the cyst, if it is possible to approach the cyst through the dorsal midline of the cord. The introduction of a small strip of folded gutta-percha held in place by a silk ligature has also been useful in the prevention of refilling of the cyst.

It is impossible completely to remove gliomatous lesions of the cord, since there is no line of demarcation permitting enucleation. A heroic attempt at removal is more likely to increase the symptoms of paraplegia than it is to reduce those already present. When such a condition does exist, it has been learned that a longitudinal section of the cord, extended into the mass of the tumor for its entire length, has proved to be of value in allowing the tumor slowly to extrude itself and thus relieve pressure on the noninvolved nerve tracts.<sup>23</sup> Hemangio-endotheliomata frequently can be removed by exposing them through a longitudinal incision of the cord, bearing in mind the fact that a dorsal midline incision without injury to the dorsal artery produces less motor disturbance than do lateral or anterior incisions. Although most intramedullary tumors are elongated masses which increase the size of the cord so that it has the appearance of a sausage, ependymomata of the spinal cord proper are found to be the longest of the group. Since they are fairly well circumscribed, although not definitely encapsulated, they do lend themselves to radical removal.

*Ependymomata of the Filum.*—Ependymomata originating within the filum, or even as high as the tip of the conus medullaris, represent a rather interesting group of tumors, since they may grow to considerable size, filling the lumbar and sacral canals before they produce paraplegia. These tumors are not encapsulated, but they are surrounded by pia mater. They produce marked erosion of the bone without invading it; grow in between the nerve roots of the cauda equina; increase the size of the lumbosacral canal; may enlarge the intervertebral foramen, and grow into the soft tissues of the back—but they apparently do not metastasize. The surgical problem that faces one, then, is to perform extensive laminectomy in order thoroughly to uncover the tumor, and then to proceed with careful dissection and removal of the tumor without impairing the blood supply or damaging the nerve roots.

## INTRASPINAL TUMORS

Complete removal will result in a cure; failure to do so will result in recurrence.

*Vascular Tumors.*—Under the heading of "vascular tumors" we include hemangioma and hemangio-endothelioma. These may be situated extradurally, subdurally (but extramedullary), and intramedullary. They are usually benign and are fairly well encapsulated, but they are extremely vascular. The extradural lesions are flattened, elongated masses, whereas the intradural lesions are usually oval in appearance. The vascular tumors are usually operable, but extreme care is necessary in removing the tumor in order to avoid injury to the blood supply of the spinal cord. In addition to the typical vascular tumor, we have encountered several vascular lesions which would have to be classified as "varicosities of the cord" and "arteriovenous fistulae." In these instances, the task of the surgeon is to reduce the varicose mass in size by ligation and resection and by the employment of electrocoagulation; he should bear in mind, however, that the blood supply of the spinal cord itself or of the nerve roots must not be injured.

*Chordomata.*—Chordomata originate from the notochord, and although their site of predilection is the sacrum, and the clivus blumenbachii, they may originate in other portions of the spinal column. These tumors erode and invade the bony structure and fill the spinal canal, producing compression and destruction of the nerve root and the spinal cord. They are primary malignant tumors, but since their growth is slow and is accompanied by pain, the surgeon is frequently justified in attempting radical removal. Although situated in the sacrum, these tumors produce an explosive type of enlargement, that is, an erosion with an invasion of the bone and elevation of isolated fragments of bone on the periphery of the tumor. Following radical resection of these tumors, roentgenotherapy appears to offer additional relief in controlling the growth of the tumor and in retarding the process of recurrence.

*Bony Lesions Which Produce Compression of the Cord.*—Hemangioma of the vertebrae result in osteoporosis and flattening of the body with compression of the cord. Occasionally, unilateral laminectomy, acting as decompression, offers some relief, but if such a procedure is employed, a cancellous bone graft should be inserted along the unoperated side.

Neurologic symptoms accompanying *tuberculous* involvement in the body of the vertebrae are usually relieved by placing the patient in hyperextension on a specially adapted frame. As the symptoms subside, the orthopedic surgeon usually inserts a bone graft as an additional support to prevent a collapse of the body of the vertebrae. However, if the neurologic symptoms fail to improve after hyperextension, the surgeon is justified in carrying out hemilaminectomy for decompressive purposes. Usually there is found an increased amount of granulation tissue within the extradural fat. Although removal of such tissue may be justifiable, extreme care should be taken to avoid an injury to the dura, since the dura acts as a barrier to the invading tubercle bacilli.

*Foreign-Body Giant Cell Tumors* may be recognized by roentgenographic observation. Since these lesions are benign, they lend themselves to surgical treatment which consists of laminectomy and removal by curet of the contents within the cystic cavity. This, in turn, relieves pressure on the meninges and spinal cord.

*Myelomata*.—At the onset, spinal myelomata may be single or multiple. When a single myeloma is encountered, the surgeon is tempted to try radical removal in order to decompress the spinal cord, but the procedure is rarely justifiable, since recurrence is sure to take place and other lesions soon follow. Roentgenotherapy has proved of very little value.

*Osteogenic Sarcomata*.—Although usually single at the onset, osteogenic sarcomata of the spinal column will recur and metastasize. The temporary relief obtained by radical removal, in order to decompress the spinal cord, is occasionally indicated, especially if osteogenic sarcomata involve the laminae and spinous processes.

*Osteochondromata*.—These may be benign at the onset but frequently become malignant; they originate in the intervertebral disk and the adjacent vertebrae. Growth of such a lesion into the spinal canal produces symptoms similar to those of any extradural tumor,<sup>33</sup> a point which emphasizes the fact that early recognition is essential and that a radical operation should be performed even though it becomes necessary to insert a bone graft to support the noninvolved portion of the spinal column.

*Paget's Disease*.—In a number of instances, the squashing process of this disease produces radiculitis and, occasionally, symptoms of compression of the cord. Again, it is doubtful whether decompression of the cord is indicated, since the relief obtained is of such temporary nature.

If either *hypertrophic arthritis* or *osteitis* extends into the spinal canal, the roots may become involved and the spinal cord compressed, with the resulting symptoms of transverse myelitis.<sup>31</sup> If it is possible to determine by neurologic and roentgenographic examination that the process is fairly well localized, and if it has been recognized in the early stages of the disease, it is possible to obtain satisfactory results by means of wide and extensive laminectomy over the involved portion of the cord. Occasionally, it becomes necessary to unroof the nerve roots as they pass through the intervertebral foramina.

*Protruded Intervertebral Disks*.—The subject of protruded intervertebral disks has received unusual attention in the last few years,<sup>26, 27, 28, 30</sup> due to the fact that tumor-like masses can be recognized by roentgenologic examination of the spinal canal by employing radiopaque oils or air. The finding of these masses in patients suffering from chronic, recurring sciatica has led to exploratory laminectomies and removal of the masses which were producing pressure on the nerve roots. The relief obtained from the surgical treatment of this condition has more than justified these newer procedures in the treatment of chronic, recurring sciatica when physiotherapeutic measures have failed. The lesions occur as the result of a tear in the annulus fibrosus, and

## INTRASPINAL TUMORS

a rupture of the intervertebral disk with an expulsion of a portion or all of the nucleus pulposus. Although the condition had been recognized, and occasionally treated, for a number of years, its importance was not emphasized until the introduction of roentgenographic studies made with the aid of radioopaque oil. These tumor-like masses, the nucleus pulposi, are not neoplastic, even though they produce symptoms similar to those caused by intraspinal tumors. After recognizing the lesion by the aid of the clinical history, neurologic observations and roentgenographic studies, they can be readily removed through hemilaminectomy, removing a portion of one and occasionally two laminae at the site of the lesion. The ligamentum flavum has frequently been ruptured and hypertrophy has taken place, so that it becomes necessary to remove the affected ligamentum flavum with the protruded disk. The involved spinal root is found to be compressed between the protruded portion of the nucleus pulposus and the pedicle of the vertebrae opposite the intervertebral foramen. Removal consists of dissecting free the edematous root and retracting the dura toward the midline, following which the completely prolapsed nucleus pulposus may be found to be lying free within the canal and can be removed without further dissection. If the protrusion is incomplete, it may be necessary to use a sharp knife or even a curet to remove the partially dislodged nucleus pulposus. The dura is not opened unless radiopaque oil has been used, in which event the oil should be thoroughly removed before closing the incision. The protruded masses are usually single, may be multiple, and are usually situated lateral to the posterior longitudinal ligament. They have occasionally been found to be situated in the midline when the protrusion is situated at the lumbosacral junction. When that does occur, transdural removal may be required. The largest number of protrusions occur in the lumbar and lumbosacral regions, but they may occur in any part of the spinal column. The second most common site of occurrence is the cervicothoracic region.

*Hodgkin's Disease or Echinococcus Cysts* may enter the spinal canal through the intervertebral foramen, and when they do so they are found to be situated extradurally, producing symptoms referable to the cord by extradural pressure. Usually, these masses can be removed by means of routine laminectomy without opening the dura, just as a surgeon would remove an extradural neoplasm. If the lesion is recognized as that of Hodgkin's disease, there being other manifestations, it is wise to employ a course of deep roentgenotherapy before resorting to laminectomy. On the other hand, if the symptoms of paraplegia are very pronounced, it may be unwise to defer laminectomy. In some instances, the operation has been performed first and then the roentgenotherapy has been employed.

*Metastatic Lesions of the Spinal Column.*—Metastatic lesions of the spinal column produce symptoms similar to those of intraspinal tumors except that they develop much more rapidly than do benign lesions. They occur at a later age than the average intraspinal tumor does, which should make the surgeon extremely careful during examination of the patient to determine, if

possible, the presence of a primary lesion. Exploratory laminectomy is rarely indicated, since removal of one metastatic nodule accomplishes so little that it is scarcely justifiable. Occasionally, an operation must be performed when no primary lesion has been located, and there is some doubt as to whether the lesion is malignant.

*Inflammatory Lesions; Chronic Radiculitis and Meningomyelitis.*—These are capable of producing symptoms simulating intraspinal tumors, but fortunately, studies of the spinal fluid, of jugular pressure (Queckenstedt test), which are employed to determine the presence or absence of an intraspinal block, and roentgenographic examinations made with the aid of radiopaque oil have made it possible to differentiate these lesions from true neoplasms. It is obvious that surgical treatment is not indicated in this group of lesions.

*Suppurative Lesions.*—Suppurative lesions, such as extradural and intra-medullary abscesses, rarely occur and can be differentiated and localized by the usual diagnostic methods, taking into consideration, of course, the fact of the accompanying suppurative infection and the rapidity with which symptoms of compression or destruction of the cord result. Surgical drainage has proved to be most effective in the treatment of this condition, but if it is employed, it should be instituted before the symptoms of transverse myelitis are complete.

*Postoperative Care.*—Following the operation, the patient is placed in bed in the lateral position on pillows, to avoid undue pressure on the tips of the shoulders and on the hips. It is preferable to turn the patient from side to side and on the abdomen, rather than to allow him to lie on his back, because sweating may result in maceration of the skin and contamination of the incision, and may interfere with primary union. The patient, otherwise, is treated as is the average surgical patient. If urinary incontinence is present, it is safer to insert an indwelling catheter rather than to repeat catheterization daily. As an additional prophylactic measure, the patient should receive 15 Gm. of sulfanilamide daily. The catheter should be changed every four or five days, and the bladder irrigated twice daily with an antiseptic solution. Usually, daily doses of mineral oil combined with milk of magnesia are administered to prevent distention and fecal impaction. In addition, a daily enema is necessary. The patient is kept in bed for two weeks, at the end of which period he is permitted to sit in the upright position in bed; he is subsequently allowed to be taken about in a wheel chair and to walk, if possible. The usual postoperative course continues for three weeks. Physiotherapy is advised if muscular cramps and motor weakness exist. Indwelling catheters should be removed permanently when the patient has recovered sufficient control of the bladder to empty it thoroughly.

Contractures and defensive reflex spasms are corrected and relieved during the period of convalescence by the application of Buck's extension to the feet and legs while the patient is in the reclining position. The recovery of motor, sensory, vesical, rectal and sexual functions takes place in the reverse order of their previous disappearance.

CONCLUSIONS

The frequent occurrence of primary intraspinal tumors, which are usually benign and operable, justifies thorough examination of all patients who complain of root pain or of progressive motor or sensory disturbance of the extremities. The diagnostic methods at our disposal will invariably affect the differential diagnosis. Surgical treatment, if it is to be instituted, should be employed before the patient becomes paralyzed.

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## CERVICAL RIBS AND THE SCALENUS MUSCLE SYNDROME \*

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BY A STUDY of comparative anatomy, one is able to tell why cervical ribs occur, to predict any anatomic arrangements such ribs may assume and, by further study of embryology, to tell why certain ribs produce symptoms.<sup>1</sup>

There are certain fish, such as skates and sea-horses, which have no ribs (Plate I, Fig. 1). There are other fish, as the *Dipnoi*, which have ventral ribs incompletely surrounding the body cavity and lying just inside the peritoneum (Plate I, Fig. 2). Still other fish, such as the shark and the ray, have only dorsal or pleural ribs. There are a few fish, notably the *Ganoidei Polypterus*, which have both ventral and dorsal ribs, two pairs of ribs to each vertebra (Plate I, Fig. 3). These fish, therefore, represent connecting links in the evolution of ribs.

The ribs of the *Urodela*, e.g., the salamander, are forked, being attached in two places to the vertebrae (Plate I, Fig. 4). In humans, one projection of this fork becomes the head and the other the tubercle of the rib.

The first movable ribs are seen in the *Anura*, e.g., frogs, as rudimentary movable stubs attached to the transverse processes of the vertebrae (Plate I, Fig. 5).

The ribs of lizards and crocodiles are the first to show both a dorsal bony part and a sternal cartilaginous part (Plate I, Fig. 6). Snakes have no sternum, all their ribs being of the "floating" type (Plate I, Fig. 7). In birds all the ribs are ossified from the sternum to the vertebrae (Plate I, Fig. 8). In mammals the sternal part of the ribs remains cartilaginous (Plate I, Fig. 9).

There is a wide variation in the number of ribs in different animals. Cervical ribs are often lacking in turtles; they are very short in many reptiles; and in birds the distal ends of these ribs are bent inward to protect the carotid arteries.<sup>2</sup> Ribs vary in mammals from nine pairs in the bottle-nosed whale to 24 pairs in the two-toed sloth. True ribs that reach the sternum vary from two pairs in the manatee to ten pairs in the spider monkey.

That the number of ribs in man is slowly decreasing is proved by the following observations. In fetal life ribs are temporarily present on the seventh cervical vertebra and all of the lumbar vertebrae. Also, in the human embryo rudimentary ribs are attached to the sacral vertebrae. Later on, these ribs fuse with adjacent transverse processes to form the lateral masses of the sacrum. The eleventh and twelfth pairs of ribs are of the rudimentary floating type and fail to reach the sternum. Lastly, we frequently find remnants of ribs in the cervical and lumbar regions. It is these evolutionary

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remnants, and in particular those of the cervical region, with which we are interested at this time. If these remnants are compared to those of the earlier forms, a surprising similarity is seen. Such ribs may resemble the insignificant

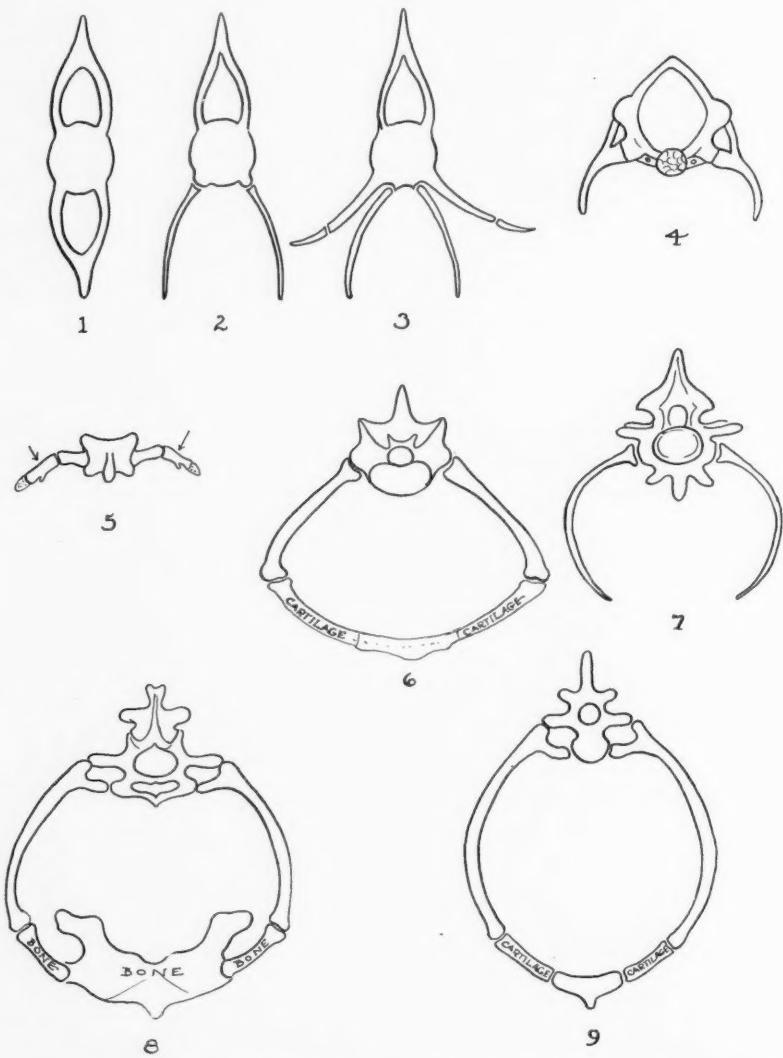


PLATE I.—Vertebrae showing types of ribs on the basis of comparative anatomy.  
 (1) Fish with dorsal and haemal spines but no ribs. (2) Fish with ventral or "fish ribs." (3) Fish with pleural and haemal ribs. (4) Salamander with short pleural ribs which closely anticipate human ribs. (5) Frog with insignificant movable rib tips. (6) Iguana or lizard with dorsal bony part and cartilaginous ventral part. (7) Ribs of rattlesnake, as pure example of floating ribs. (8) Bird ribs, solid bone, attached to vertebrae and bony breast plate. (9) Mammalian ribs with cartilaginous sternal parts.

movable tips seen in frogs; or they may at times be completely formed ribs with a vertebral and sternal attachment, as found in some of the lower animals.

Lumbar ribs are normal in gorillas and chimpanzees. They are, therefore,

called "gorilla ribs," and a fact not generally known is that they occur in man more often than do cervical ribs.\*

Why human beings get symptoms from cervical ribs, from high first ribs and from hypertrophied scalenus muscles can be well understood if one is familiar with the embryologic development and the anatomy of the structures about the upper end of the thoracic cage.

In the first place, the developing upper extremity demands, or carries with it, large blood vessels and at least six spinal nerves in the form of the brachial plexus. In quadrupeds and human embryos these blood vessels and nerves along with the ribs come off more or less at right angles to, and hang downward, as it were, from the spinal column, since the latter is carried parallel to the ground.

When human beings begin to assume the upright position, the upper extremities begin to pull downward parallel to the spine instead of at right angles to it. The same is true of all of the viscera. The brachial plexus and subclavian vessels, being on the outside of the thoracic cage, thus straddle the first rib and actually press sufficiently on the latter to the point where, in human anatomy, grooves for these structures on the first ribs are always described<sup>3</sup> (Fig. 1). If a cervical rib is now introduced, either behind or under the brachial plexus and the subclavian vessels, pressure on these structures is only increased.

Another factor producing symptoms is the action of the scalenus muscles during inspiration.<sup>4</sup> The medius is the largest and strongest. In deep respiration, this group of muscles is in full action, raising the first ribs upward along with the sternum. If the scaleni are hypertrophied, or if there is already pressure on the brachial plexus and subclavian vessels, either by an enlarged first rib or a cervical rib, symptoms from such pressure are only increased when this group of muscles is in action.

The thoracic cage in quadrupeds and human embryos is broader from front to back, whereas, in the human adult the cage is broader from side to side. This increased lateral diameter adds to the pull on the brachial plexus and the subclavian vessels as they go out and down the arm.

The clinical aspect of this paper has to do with the study of 31 cases. The anatomic types of these cases are shown in Plates II and III. Actual draw-

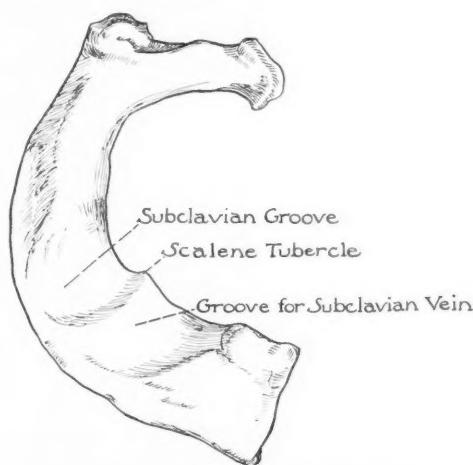


FIG. 1.—The normal first rib showing well-worn grooves for the subclavian vessels on either side of the scalene tubercle. The grooves emphasize the amount of pressure caused by the vessels (after Gray).

\*For the references to comparative anatomy, the author has drawn freely from Herbert Eugene Walter's<sup>1</sup> book.

ings of the roentgenograms were made because they show the bony anatomy more clearly than do the films themselves.

It will be seen that they fall into the following broad groups: (1) Enlarged transverse processes, usually of the seventh cervical vertebra. (2) Bi-

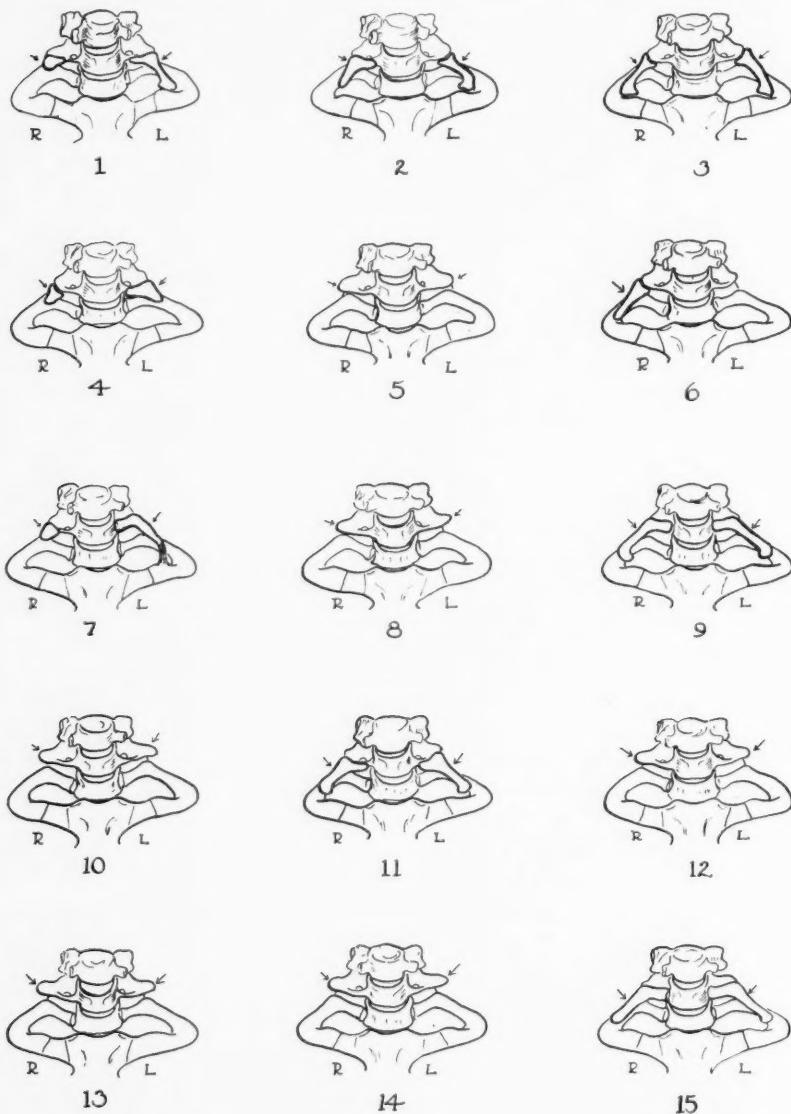


PLATE II.—Drawings from roentgenograms of 15 actual cases. Most all possibilities are found: Enlarged transverse processes; bilateral ribs of the floating type or articulating with the first rib; single ribs either floating or articulating; and rudimentary rib tips. Nos. 5, 8, 10, 12, 13 and 14 had anterior scalenus symptoms. Nos. 5, 8 and 14 were operated upon with relief of symptoms.

lateral ribs of the floating type, or bilateral ribs articulating with the first rib. (3) Unilateral ribs, either floating or articulating with the first rib. (4) Rudimentary rib tips, either single or bilateral. One case (Plate III, Fig. 20)

## CERVICAL RIBS

showed rudimentary rib tips at the sixth cervical vertebra and fully developed ribs from the seventh cervical vertebra. The cases with a single rib, with or without a rudimentary tip on the opposite side, were three times more

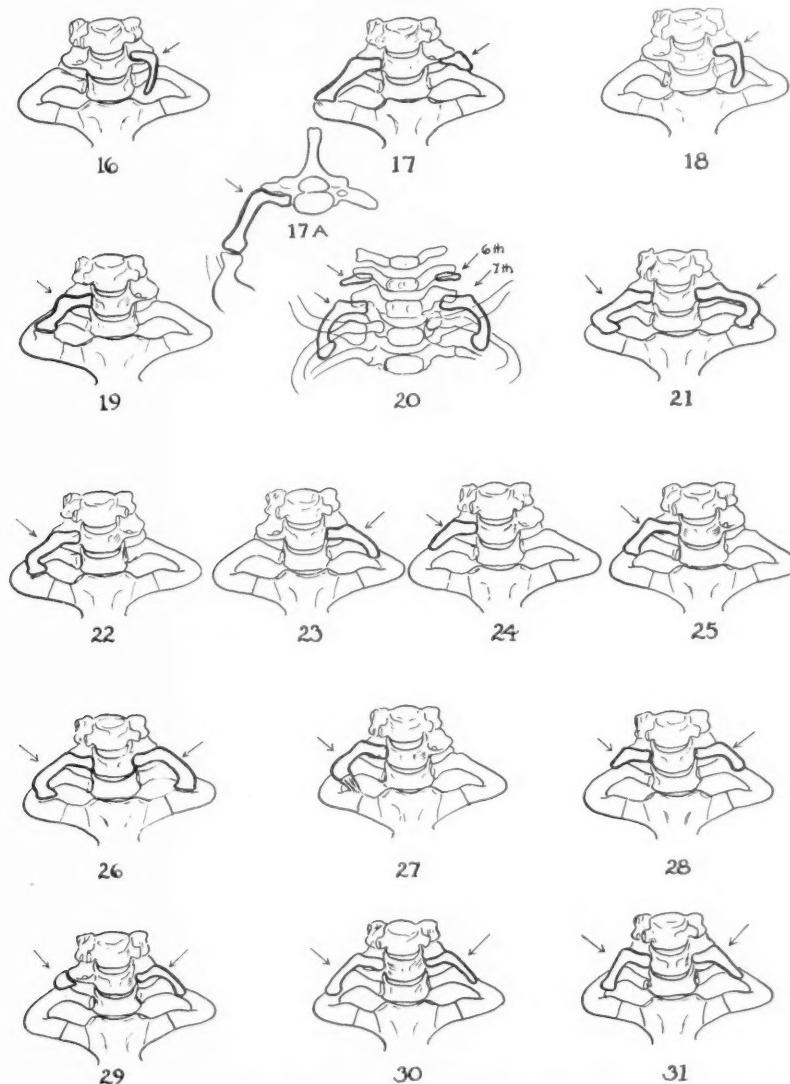


PLATE III.—Drawings from the roentgenograms of 16 more actual cases. Number 20 is unique, in that there were rudimentary sixth cervical rib tips and well developed seventh cervical ribs. This case was a full term stillbirth.

frequent than the cases with bilateral ribs. The cases with enlarged transverse processes and those with bilateral ribs were about equal in number.

Sixteen of the 31 cases had symptoms. The symptoms were always related to pressure or irritation of some part of the brachial plexus or subclavian artery. Although the lower nerves of the brachial plexus were more

commonly involved, all of the components of the plexus were in one case or another affected. Sometimes the symptoms were at the base of the neck, again they were about the entire shoulder, or the upper arm, or the lower arm, or the hand, or any combination of these. The patients' complaints, in their relative frequency, were as follows: Pain of varying intensity; tiredness and weakness of the extremity; cramps in the fingers; numbness, tingling or coldness of the hand; areas of hyperesthesia; shrinking of some of the muscles of the hand; a lump at the base of the neck; tremor of the fingers; discoloration of the fingers. The symptoms were increased from month to month. They grew worse with the day's progress. Work and exercise accentuated the symptoms. All of the symptoms were in part relieved by elevation of the upper extremity and by rest.

The cases with symptoms will be considered in two groups, ten with cervical ribs, and six with enlarged transverse processes and belonging to the so-called scalenus syndrome group.

Of the ten cases, three had symptoms on the right side, six on the left side, and one case had symptoms on both sides. In every case the symptoms were on the side where the cervical rib was the larger. Two cases were male and eight were female. All the cases were between the ages of 20 and 31.

Seven of the ten rib cases with symptoms were operated upon. The same operation was performed in each instance. The skin incision was made at the base of the neck, bisecting the angle formed between the sternomastoid muscle and the clavicle. The phrenic nerve was isolated, the subclavian artery was identified, the scalenus anticus muscle was divided, the brachial plexus was identified, the scalenus medius muscle was divided at its upper portion. The cervical rib was rongeured away in small bits and the wound was closed in layers. A few points to be emphasized in surgical technic are as follows: As described in a previous communication,<sup>5</sup> we still use the lower half of the scalenus medius muscle as a tractor against the brachial plexus. We again want to emphasize the fact that retraction or even moderate pulling on the brachial plexus will produce symptoms for months after the operation. Secondly, we wish to advise that the scalenus anticus muscle be divided one to two inches or more above its first rib attachment, because of the fact that the pleura so frequently comes up behind this muscle and sometimes a full inch above the first rib (Fig. 2). It should be noted that with an extra rib we have one more intercostal space with a probable enlarged pleural cavity. We have seen the pleura nicked or opened on two occasions. In each instance the opening was quickly covered with moist cotton and later on by a good piece of muscle. No harm resulted. The "fibrous band," often spoken of, has been found in two of our cases (Plate II, Fig. 7, and Plate III, Fig. 23). In one instance, the band extended from the tip of the rudimentary rib downward and along and continuous with the sheath of the scalenus medius muscle. In the other instance of the "fibrous band," the latter extended from the tip of the rib over to the scalene (Lisfranc's) tubercle. We believe in dividing the anterior scalenus, and the middle scalenus muscle, and in rongeuring most

of the cervical rib away whenever it is present. Of the seven operated cases, six are now symptom-free.

There were six cases with anterior scalenus syndrome. All were females. Three had symptoms on the left side and three on the right side. All of the patients were between the ages of 20 and 30 except one woman, who was 40.

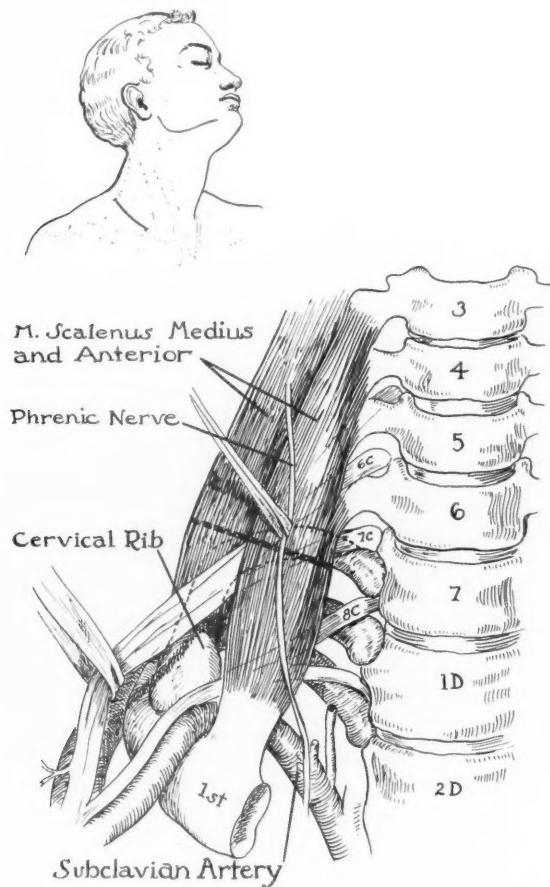


FIG. 2.—The transverse black line is the level at which we suggest division of the scalene muscles. There will be less danger of injuring the pleura which is often one space higher in cervical rib cases. The insert shows the line of the skin incision which bisects the angle formed by the sternocleidomastoid muscle and the clavicle. (Redrawn from A. W. Adson<sup>8</sup> and W. C. Carroll.<sup>12</sup>)

Three of the six cases were operated upon. The operative incision was the same as that employed for the cervical ribs, the anterior scalenus merely being divided. The scalenus muscle in each instance was enormously hypertrophied, being three or four times its normal size in two of the cases. Of the three cases not operated upon, the symptoms were not severe enough to warrant operative interference.

Even with a well-developed cervical rib, a correct diagnosis is frequently very difficult to make, and without the cervical rib, the statement is even more

true. There are cases, although they are very rare, where serious interference with the circulation is evidenced. In such cases a diagnosis, as quickly as possible, followed by operation, is indicated. In all of the rest of the cases, if a careful study is not made, useless operations may result. It may be of interest to briefly cite the following cases:

#### ABBREVIATED CASE REPORTS

**Case 1.**—The patient, a female, age 35, complaining of soreness in the right shoulder, right side of the neck and pain radiating down the lateral aspect of the whole right arm, was found to have a back strain associated with spina bifida occulta of the seventh cervical and the first dorsal vertebrae (Fig. 3).

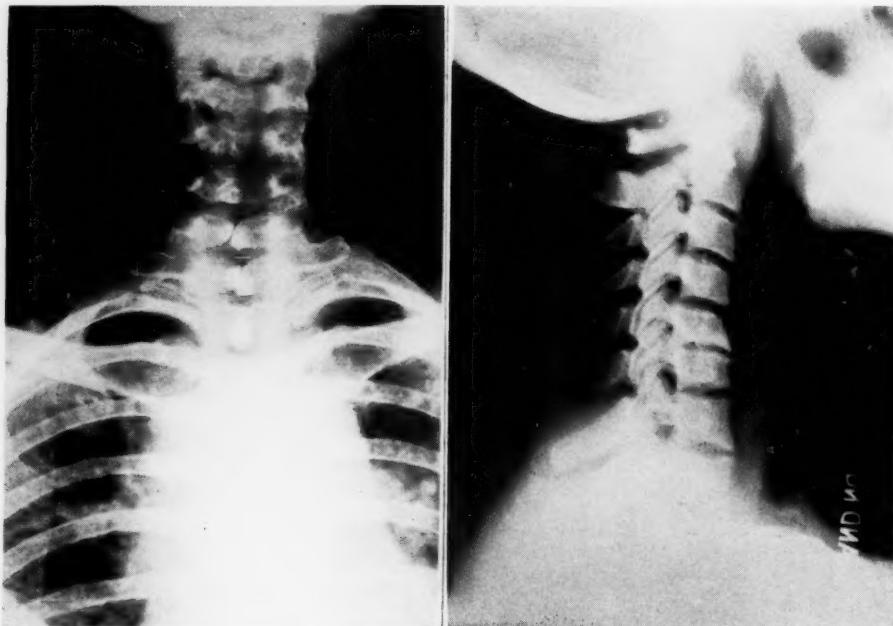


FIG. 3.—Case of seventh cervical spina bifida with symptoms at first thought to be due to the scalenus syndrome.

FIG. 4.—Arthritis of the fifth and sixth cervical vertebrae producing symptoms very similar to cervical rib. Note the absence of the normal anterior neck curve, the diminution in the space between the affected vertebrae, and the narrowing and lipping present.

**Case 2.**—The patient, a female, age 30, complained of cervicodorsal pains after working for long hours, pain in the right shoulder after sitting in one position for a long time, and she felt a bony mass in the right supraclavicular region. This patient was found to have an enlarged seventh cervical transverse process, spina bifida with structural defects of the laminae of the first dorsal vertebra, and a congenital deformity of the scapula.

**Case 3.**—The patient, a female, age 27, four feet nine inches tall, complained of numbness in both arms, especially the right, which was more marked at night after typing. Roentgenologic examination showed marked arthritis between the fifth and sixth cervical vertebrae with marked hypertrophic changes in the adjacent surfaces of the vertebral bodies (Fig. 4).

**Case 4.**—The patient, a male, age 40, complained of "pins and needles" from the right elbow to the ends of his fingers. When he tipped his head back, the symptoms were

## CERVICAL RIBS

increased. His little finger and half of his ring finger felt cold most of the time. Examination showed him to have an old anterior subluxation of the right shoulder with pressure on the brachial plexus.

**Case 5.**—The patient, a female, age 29, known to have rheumatic heart disease, complained of pain in the left side of the neck, over the left shoulder, along the lateral aspect of the left arm, and the dorsum of the hand. Roentgenologic examination showed her to have very large transverse processes of the seventh cervical vertebra. It was not thought that the symptoms were the result of her cardiac condition. She was observed over a period of one year, during which time her symptoms disappeared.

**Case 6.**—The patient, a male, age 24, complained of pain at the base of the left side of his neck and the muscles of the superior and lateral aspects of the shoulder. Roentgenologic examination of the cervical spine showed a questionable tuberculous lesion and

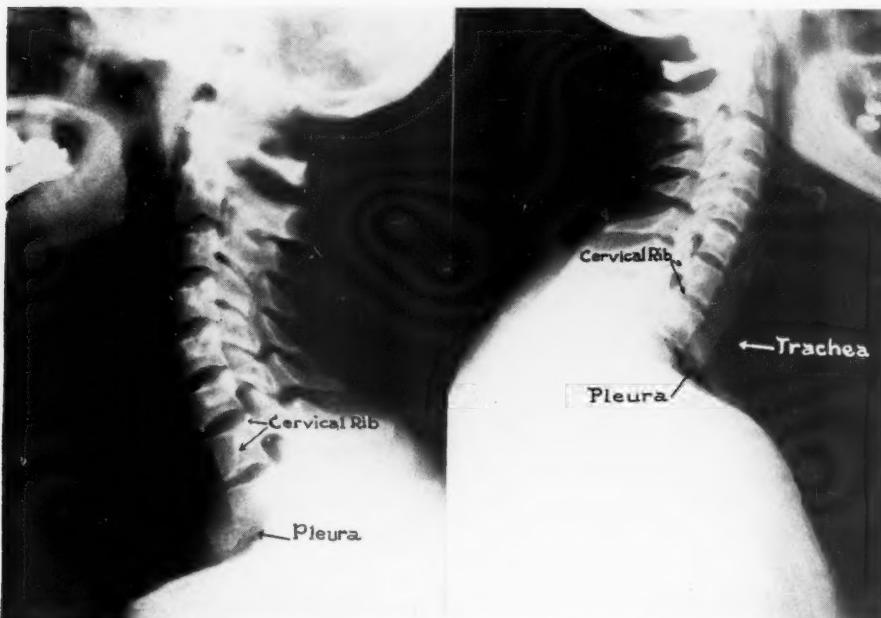


FIG. 5.—This is Case 1 of Plate II in the lateral view, showing the cervical rib as a faintly white, exclamation point shadow lying obliquely across the seventh cervical vertebra. The pleura is seen as an oblong shaded area in front of the base of the neck.

FIG. 6.—This is the lateral view of Case 4 of Plate I. The cervical rib is seen, the trachea and pleural dome are clearly shown. At operation the pleura is in constant danger of injury.

treatment, predicated upon such a diagnosis, was being considered when further roentgenograms, taken elsewhere, showed a cervical rib, which was found to be responsible for the symptoms.

**Case 7.**—The patient, a female, age 29, developed pain in the left shoulder, particularly in the scapular region. She was referred for roentgenologic examination of the teeth and chest, and her cervical spine was not shown in the films. Physiotherapy treatment for subdeltoid bursitis was advised. The symptoms increased and extended down the lateral aspect of the shoulder, upper and lower arm, and marked tremor developed in the left hand. She was operated upon elsewhere, at which time a typical, rudimentary seventh cervical rib was found on the left side, removal of which relieved her of all symptoms.

Any vascular disease, such as Raynaud's disease or thrombo-angiitis obliterans, may produce symptoms of cervical ribs. Ray<sup>6</sup> has recently re-

ported a group of cases of tumors of the "apex of the chest." Symptoms from these are at times not unlike those from cervical ribs. Reid<sup>7</sup> reported a few cases of cervical rib with symptoms very closely simulating those of angina pectoris or coronary thrombosis, and he called attention to the fact that such patients were likely to be referred to the Cardiac Clinic.

In addition to the ordinary roentgenograms taken, we want to mention a few observations not commonly described: (1) In the lateral view, the cervical rib will frequently be shown as an oblique, faintly white streak running downward across the body of the seventh cervical vertebra. This streak sometimes looks like the outline of a calcified tadpole (Fig. 5). (2) Also, in the lateral view of a patient with a long neck, a dark, oblong shadow may frequently be seen in front of the lower cervical vertebrae. The center of this shadow lies between the lower cervical vertebrae and the trachea (Fig. 6). This represents the pleural cavity or lung, and only emphasizes the suggested technic of dividing the anterior scalenus muscle higher than is generally advised. (3) As previously suggested by us,<sup>5</sup> a cervical rib is sometimes best demonstrated by placing the patient in an oblique position and having him take a swallow of a barium meal. The rib will be seen at the top of the column of barium passing through the esophagus.

**DISCUSSION.**—Recently, the impression has become rather general that in all cases of cervical ribs, symptoms can be entirely relieved by a simple division of the anterior scalenus muscle. The largest number of cases so treated has been reported in several papers from the Mayo Clinic.<sup>8</sup> But in the summary of one of the papers, Craig and Knepper<sup>9</sup> make the following statement: "In the presence of a cervical rib without tendinous attachments and without obvious pressure from behind, resection of the scalenus anticus muscle is all that is necessary, but when there is evident pressure from the cervical rib or its tendinous attachment, resection of the rib and the attachment should be carried out." With this statement there can be very little argument.

Cases of anterior scalenus syndrome now greatly outnumber those with cervical ribs, and the symptoms of the two are very similar. Since division of the scalenus muscle so frequently relieves both conditions, there is a tendency to regard that procedure as sufficient in all cases. If the surgeon elects, simple division of the anterior scalenus muscle may be first tried. If the symptoms are not relieved, the cervical rib may be removed at a later operation. We have found that it is technically not difficult to carry out both procedures at one operation. If one is not experienced in neck surgery, the simple muscle division, of course, would be the better. Removal of the cervical rib requires a longer incision and it takes about twice the length of time as the simple muscle division. We have not noted any deaths resulting from the rib operation. In cases of impending gangrene of the fingers, or serious vascular symptoms, I would advise removing the cervical rib, if one were present.

There is evidence to prove that long continued pressure of the cervical

rib on the brachial plexus brings about a chronic aseptic inflammatory reaction which, if continued long enough, may bring about a permanent fibrosis.<sup>10</sup> Such a fibrosis may account for the failure to relieve symptoms following even the more extensive operation for cervical ribs. I have had one such case, in which the anterior and middle scalenus muscles were divided and the rib was removed. This patient was reported as Case 2 in a previous article.<sup>5</sup> Her symptoms apparently cleared up a few months following the operation but very soon recurred. She was seen recently, and her arm still bothered her. Of course, at operation we may have traumatized the brachial plexus.

Whereas, in the first part of this present communication, we dealt with developmental facts as to why cervical ribs are formed and why they give symptoms, still, there is no question that there are, many times, other contributory factors: Trauma, either on one occasion or continued over a period of time, plays an important rôle. Anatomic variations are at times most important, as: (1) First ribs which are unusually high, very large, or irregularly curved. (2) The anterior scalene tubercle may be greatly enlarged. (3) The brachial plexus may come off one segment higher or lower, and it may vary in its branching combinations. (4) The right subclavian artery may even come directly off the aortic arch<sup>18</sup>; the artery or the vein may pass in front of, behind or through the anterior scalenus muscle. (5) Bony deformities of the chest may broaden or shorten the lateral diameter of the entrance to the thoracic cage. (6) Curvatures of the spine may bring about an unusual pull on the first rib or the cervical rib. (7) It is generally thought that with advancing years the shoulder girdle descends and thus further angulates the brachial plexus and the subclavian vessels as they pass over the first rib.

In 1916, Halsted<sup>11</sup> reported 716 cases of cervical ribs recorded in the literature to that time. Halsted was especially interested in aneurysms or dilatations associated with cervical ribs, and he found 27 such instances. Adson<sup>8</sup> states he has never seen an aneurysm associated with cervical ribs. We have seen arteries compressed either by the rib or the scalenus muscle and, immediately following the operation, have seen rather dramatic restoration of the artery to its normal size. There have been cervical rib cases with aneurysms and syphilis.<sup>14</sup> There is, of course, a certain percentage of people without cervical ribs who develop subclavian aneurysms. There have been only a few cases of complete obliteration of the subclavian artery. One such case was reported by Olijenick,<sup>13</sup> in Cushing's Birthday Volume, one by Lindskog and Howes,<sup>14</sup> and one by us,<sup>5</sup> in 1935. Due to its unusual subsequent course, our case is reported somewhat in detail:

**Case Report.**—A. M., female, age 31, had bilateral cervical ribs articulating with the first ribs. For six months she had had symptoms on the left side, consisting of coldness of the extremity and weakness in the hand and arm. There was no pulse palpable in the extremity, and at operation the subclavian artery was found to consist of a fibrous, avascular cord. The anterior and middle scalenus muscles were divided, the cervical rib was rongeured away, and the patient made an uneventful recovery. Her symptoms disappeared but she has never had a palpable pulse in that extremity since.

On May 13, 1938, three years after the first operation, the patient returned because she had for several months been noticing increasing numbness of the right upper extremity and, in particular, the fingers of the right hand. Her symptoms were more marked when she tried to bend over.

*Physical Examination.*—Blood pressure in her right arm was 110/60, whereas, in her lower extremities the blood pressure was 142/80. Since her symptoms were increasing, since she had previously lost the main artery to her left upper extremity, operation was urged and was performed three days later.

*Operation.*—The subclavian artery was compressed forward against the anterior scalenus muscle by a large cervical rib which articulated with a large scalene tubercle. The artery appeared to be bent over the cervical rib. The anterior scalenus muscle was divided two inches above its insertion. The artery was still narrowed and the cervical rib still pressed upon it. The rib was then rongeured away. The artery then fell back into the space occupied by the rib. It was remarked that the subclavian artery was 40 per cent larger at the end of the operation than at the beginning. The brachial plexus, as was the case on the left side, was postfixed in type. The cervical rib passed through the middle of the plexus. Following operation the patient's symptoms were immediately relieved and she has remained symptom-free.

Circulatory disturbances are now regarded as due to a constant stimulation of the sympathetic (constrictor) nerve fibers of the artery to the extremity,<sup>10, 15</sup> or else there is direct pressure or angulation of the vessel. In any event, the pathologic process is supposed to take place over a long period of time and, from other observations in vascular surgery, one would think it much better to bring about a gradual diminution in size of the artery, thus giving collateral circulation a chance to fully establish itself. Quite contrary to this idea, and very practical to know, is the manner in which some surgeons have dealt with aneurysms associated with cervical ribs: In addition to the rib operation, at least in one instance,<sup>16</sup> the aneurysm was doubly ligated *in situ*, and on another occasion<sup>17</sup> the aneurysm was removed by immediate double ligation. In both instances there was a good postoperative recovery.

#### CONCLUSIONS

- (1) The occurrence of and the symptoms from cervical ribs are explained on the basis of comparative anatomy and embryology.
- (2) During inspiration the scalenus muscles may cause pressure or accentuate rib pressure on the brachial plexus and the subclavian vessels.
- (3) Anatomically, cervical ribs may be divided into four broad groups: Those with enlarged transverse processes; bilateral ribs, either floating or articulating; unilateral ribs, either floating or articulating; rudimentary rib tips, either single or bilateral.
- (4) The chief complaint of the patient is pain of varying intensity. The pain may be in any part of the neck, shoulder or the upper extremity.
- (5) At operation we advise division of the anterior and medial scalenus muscles and removal of the rib, if present. We also suggest division of the anterior scalenus through the muscle belly so as to avoid the pleura.
- (6) The dome of the pleura is probably higher in the neck of people with cervical ribs.

(7) In the differential diagnosis, even if a cervical rib is present, the following conditions should be excluded: Arthritis of the spine or shoulder, bursitis, apical tumors, neuritis, vascular diseases, congenital deformities, and cardiac diseases.

(8) Lateral roentgenograms will frequently show the cervical rib running diagonally across the body of the seventh cervical vertebra; they will also show the pleura at the base of the neck in front of the spine.

(9) Aneurysms of the subclavian artery caused by cervical ribs or anterior scalenus syndrome are very rare. The aneurysm, if present, may be doubly ligated and resected, or not, with safety.

(10) Circulatory disturbances are probably due to repeated stimulation of the vasoconstrictor nerves, or to direct pressure on, or angulation of, the subclavian vessels.

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DISCUSSION.—DR. WILLIAM DEW. ANDRUS (New York) said that the difficulty in differential diagnosis of both cervical rib and the scalene muscle syndrome is evident. Doctor Smith's case illustrated the widespread symptoms that may occur from another type of abnormality in this region and Doctor Patterson brought out in connection with two cases that other lesions may give rise to symptoms similar to those caused by cervical ribs. In the

New York Hospital, during the last few years, there have been seven cases of cervical rib or scalene syndrome. Five had cervical ribs—three were complete articulating ribs and two were with a fibrous band. Two cases were of the so-called scalene syndrome. One patient was a woman, age 52, who complained that she woke up every morning with a swollen left hand and cyanosis of the finger tips. On further inquiry it developed that she always slept on the left side and used a high pillow. She would turn on the right side for relief. She was observed for several days and, as roentgenograms showed no evidence of cervical rib, a diagnosis of scalene anticus syndrome was made. She was completely relieved following the section of the muscle.

So many anatomic abnormalities can occur in this region that it is difficult to implicate any single one. Emphasis has been placed on hypertrophy of the scalene anticus muscle as being of considerable importance, more so perhaps than the alleged inflammation supposed to occur according to some of the earlier reports. The reason for the hypertrophy, however, remains obscure in many cases. It can be explained in some instances by a more than usually vertical position of the first rib, in which case the angle at which the scalene muscle acts to elevate the rib is more acute, thus requiring more force to raise it, and also making the angle through which vein and artery must pass more acute and accentuating the pressure exerted upon them.

DR. BEVERLY CHEW SMITH (New York) said that the presence of cervical rib should be suspected in all cases of neural or vascular symptoms in any upper extremity. Whereas the actual presence of a rib can be revealed by roentgenologic examination and, in some cases, by palpation, quite often symptoms associated with actual cervical rib persist in the absence of a demonstrable rib. This later condition is recognized to-day as the scalene anticus syndrome and is associated with a tense deep cervical fascia posterior to the scalene anticus, an hypertrophied muscle or a band from a transverse process to the first rib. The relief of symptoms following the division of the scalene anticus in these cases has been so brilliant that it has led to the assumption that muscle division alone will relieve symptoms in the presence of actual cervical ribs. This is not wholly true, as in those cases where the ribs are sufficiently large and the plexus is more caudally fixed, excision of the rib is required to give permanent relief. Doctor Patterson stresses in his technic the value of the scalene medius as a tractor after its division in protecting the plexus during extirpation of the rib. This point should be borne in mind if rib resection is necessary. The multiplicity of vague symptoms from vascular spasm, intermittent claudication, arterial subclavian occlusion, gangrene of digits, cardiac palpitation, nausea and faintness, makes cervical ribs and associated scalene anticus syndrome a major surgical diagnostic problem.

Doctor Smith said he believed it expedient in all operations for cervical rib or scalene anticus syndrome to divide the fascia posterior to the scalene anticus after division of the muscle; for not until this is done will the plexus or subclavian artery be freed of the pressure upon them anteriorly.

Diagnostic exploration of the scalene region is indicated in cases of this syndrome in the absence of roentgenographic evidence of cervical ribs, if symptoms are progressive, unrelieved by palliative treatment, or are exaggerated by position associated with increasing symptoms in the presence of actual cervical ribs.

DR. JOHN M. HANFORD (New York): There are a great many phases of this subject which one might discuss. I would like to speak first about conservative treatment. It seems to me that occasionally there may be justifica-

tion for trying this. The main indication, I would say, would be the absence of organic disease—that is, symptoms without evidence of organic disease. Dr. Walter M. Brickner, twelve years ago, gave a very interesting discussion of pressure upon the brachial plexus and upon the artery by a normal first rib, and recommended conservative treatment in certain types of cases by rest, by elevation of the arms and by such exercises as might facilitate the release of the pressure of the first rib. One might consider that treatment (especially in patients who might not be suitable for operation), if they have no organic disease or no definite evidence of damage to the circulation or nerves.

Another phase of this subject which interests me very much is the mechanism which causes the symptoms. It is easy enough to explain symptoms due to pressure upon any nerve or nerve root; but why does constriction of the subclavian artery cause symptoms even before thrombosis and actual occlusion have occurred? In some of these cases, like Doctor MacFee's, there was no apparent thrombosis or damage to the artery. There was only narrowing and a slight aneurysmal dilatation; but why was the patient having symptoms? I understand that the patient had no damage to the brachial plexus of any consequence. The subclavian artery can be ligated immediately, distal to the thyrocervical trunk, without any such symptoms. Then how do these symptoms develop? I do not know. I would like to be enlightened. It probably is known. At least there may be very good theories. But it seems to me that it must be related to the innervation of the artery, which may have something to do with the studies which Leriche made in the periarterial sympathectomies. A patient of mine, like Doctor Smith's, had thrombosis of the distal part of the subclavian artery; the artery gave no pulsation down the limb, and presented all the evidences of arterial occlusion, yet release of the artery at operation relieved her symptoms. Two months ago when I saw her (seven months after operation) she was still enthusiastic about the results of the operation which consisted of nothing but release of the artery. She had no evidence of nerve damage. How was she benefited and what mechanism caused her symptoms? That is a very interesting pathologic-physiologic study. This patient I operated upon had a thrombosis. I opened the artery, passed a probe down the axillary artery, which was completely thrombosed, and examination of the clot showed organization. Nothing was done to improve the arterial circulation. She had a cervical rib which I did not touch. She improved. Why?

Another phase of the subject is the technic. My impression is that division of the sternomastoid along the clavicle is helpful in obtaining good exposure. Very careful hemostasis is important. Division of the omohyoid is justifiable. Division of the scalenus anterior may not succeed if it is made high because, in my patient just referred to, there was dense tissue along the lower part of the muscle; and I had to divide this low down in order to release the artery. In working about the lower part of the muscle, certainly one should be careful about the pleura. The stress laid upon care in the traction upon the brachial plexus by Doctor Patterson is most important. Nerves do not withstand traction! If ever there was a sound surgical axiom, that is one. The scheme of retracting the plexus very gently is most important.

DR. RUSSEL H. PATTERSON (closing) said that in every case the symptoms were on the side where the rib was largest. He agreed with Doctor Smith about cutting the muscle and fascia, and said that this principle was certainly true in two of his cases. If the fascia had not been cut either in front or behind the scalenus anterior or the scalenus medius, the first rib would not have been released.

## THROMBOSIS OF THIRD PORTION OF SUBCLAVIAN ARTERY ASSOCIATED WITH SCALENUS ANICUS SYNDROME\*

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**Case Report.**—E. H., male, age 28, was first admitted to Vanderbilt Clinic, September 1, 1937, complaining of palpitation of the heart of six months' duration. His past history was negative. His personal history was also negative, except that he consumed one and a half packs of cigarettes and seven cups of coffee a day. He enjoyed excellent health until September, 1935, at which time he first noticed palpitation, precordial pain accelerated by exertion, and nocturia of two to three times. During the first six weeks of this complaint he lost 18 pounds, became worried and introspective. Following palpitation he noted hot flashes, dripping night sweats, polydipsia and polyuria seven to eight times daily. His doctor told him that he had high blood pressure but did not tell him the readings. Without treatment his symptoms disappeared slowly in two months. He remained symptom-free for one and a half years except for short attacks of palpitation which recurred irregularly for a month. Six weeks before admission, his symptoms reappeared and gradually increased in intensity and frequency. The cervical nodes on both sides of his neck would swell and recede for a period of two to three hours during the day. They were not painful, but were uncomfortable. He noticed increased nervousness and irritability.

From September 1, 1937, to June 27, 1938, he was seen a number of times in various departments of Vanderbilt Clinic, where his blood pressure varied from 190/100 to 140/85. His urine was negative. The Wassermann was negative. At odd times he complained of consciousness of his heart when lying on his left side at night because of its forceful beat. He was considered a case of neurocirculatory asthenia. He became worried about himself which accelerated his symptoms. In May, 1938, pain occurred in his left shoulder radiating down to his left elbow, and at this time it was noted that, although the right radial was normally palpable, the left radial could barely be felt. The right brachial blood pressure was 165/95, the left 115/85. On May 31, 1939, roentgenogram No. 172740 was negative for cervical ribs. Transverse processes of the seventh cervical vertebra were said to be a little longer than normal.

June 6, 1935: Oscillometric readings, at 130 Mm.Hg. pressure showed:

	Right	Left
Lower $\frac{1}{3}$ arm.....	9	2
Midforearm.....	5	1
Upper $\frac{1}{3}$ leg.....	7	7

He began having intermittent claudication of his left hand and arm, to such an extent that he frequently had to rest during his work as a soda dispenser and could not work longer than four hours at a stretch without a long rest period. His symptoms became more pronounced and he noticed transient weakness in his left upper extremity associated with tremor and sweating limited to face, neck and arms. His left arm was weaker, colder and bluer than the right.

**Physical Examination.**—This was essentially negative except that the left radial and brachial pulse could barely be appreciated, and left subclavian above the clavicle could not be felt. The left nail beds were slightly cyanotic. The ulnar, radial and biceps

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## SCALENUS ANICUS SYNDROME

reflexes were less active on the left than on the right side, and there was atrophy of the left thenar eminence.

In June, 1938, his left arm frequently became numb and his capacity for using it limited its use to such an extent that he could not carry a newspaper or magazine in his hand. It became painful and felt as if it were asleep. He was breathless after climbing two flights of steps. He became conscious of holding his head bent to the right which caused his left shoulder to be higher than the right.

Blood pressure readings were as follows:

	Right	Left
Sitting with arm at side.....	165/100	115/80
Sitting with arm abducted.....	150/100	100/80
Sitting with arm overhead.....	130/50	85/75

Surface temperature in both hands and forearms was normal at 31.5° C.

Examination by the Neurologic Department revealed no disease of the spinal cord, nerves or brain.

An electrocardiogram (No. 50958) June 22, 1938, was normal.

Oscillometric Readings	Right	Left
Arms at side—midforearm.....	4.5	2
lower third of arm.....	9	3
Arms extended—forearm.....	5	1
arm.....	6	0.5
Abducted 90°—forearm.....	4	1
arm.....	6.5	2
Elevated to 180°—forearm.....	3	0
arm.....	4	0

Eye examination by the Ophthalmologic Department was negative. A six-meter roentgenogram of heart showed no cardiac enlargement. Red blood count 5,000,000, white blood count 11,450, polys 72 per cent.

*Operation.*—June 24, 1938: Under avertin-nitrous oxide-ether anesthesia, a left lateral, low collar incision was deepened through the platysma and the clavicular portion of the sternomastoid muscle; and the phrenic nerve was retracted from the anterior surface of the scalenus anticus muscle. The scalenus anticus muscle was then divided near its insertion on the first rib. The subclavian artery was exposed with the thyro- and costocervical trunks. Good pulsations were noted in both thyro- and costocervical trunk at the third part of the subclavian artery. No pulsations were felt in the subclavian distal to this point but normal pulsations proximal to this trunk were noted.

A hypodermic needle inserted into the subclavian proximal to the costocervical trunk yielded blood; lateral to this trunk no blood was obtained. The transverse scapular artery was dilated. The lateral edge of the cervical fascia posterior to the scalenus anticus muscle was a taut, hypertrophied fascial band which partially compressed the subclavian artery just distal to the costocervical trunk, where the medial edge of the thrombosed subclavian was noted. There was no pulsation in the third portion of the subclavian or the radial when this band was released.

His postoperative course was uneventful. He was discharged on the eighth postoperative day. His wound healed per primam.

*Subsequent Course.—Follow-up at three months:* The patient reported that his left arm was stronger although it still tired more quickly than the right; left forearm still remained smaller than the right. There was no coldness, cyanosis or tingling of his hand; his grasp was normal but there was no change in the thenar atrophy. The Cardiology Clinic reported a normal heart.

*Follow-up at five months.*—November 15, 1938: Left radial was found to be slightly

more palpable, both brachials were palpable but could be felt on the right much stronger than on the left. The entire left upper extremity felt much more normal. His hand did not tingle as previously. His palpitation, nocturia, polyuria and sweating had disappeared. Cold weather did not bother him as it had previously. Oscillometric readings were the same.

At ten months after operation, his left upper extremity was symptomless. He had no pain, did not become fatigued, and worked nine hours daily as a soda dispenser without intermittent claudication of his left upper extremity. He had no cardiac or chest symptoms; he was less nervous, his hand was pink, and his arm felt normal.

BP: right 160/90—left 110/80. The right radial, brachial, axillary and subclavian arteries were normally palpable, but on the left side they were felt with great difficulty and at times the pulse was imperceptible. With both hands above his head the left was paler than the right but both pinked normally when dependent.

Oscillometric Readings	Right	Left	Pulse 92
	120	100	
Lower $\frac{1}{3}$ arm .....	9.0	2.5	
	120	100	
Midforearm .....	5.5	2.0	

The patient is shown as a case of scalenus anticus muscle syndrome with symptoms simulating coronary disease, without a cervical rib but with the thickened lateral edge of the cervical fascia posterior and lateral to the scalenus anticus muscle pressing on the third portion of the subclavian artery resulting in a thrombosis which had become an organized fibrous cord. Division of the fascia, where it compressed the artery, relieved all of his cardiac symptoms, the pain in his shoulder and arm, and the intermittent claudication while at work as a soda dispenser. There was no evidence at operation of compression of the nerves of the brachial trunk.

## CERVICAL RIB CAUSING PARTIAL OCCLUSION AND ANEURYSM OF THE SUBCLAVIAN ARTERY\*

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CERVICAL RIB is usually a bilateral condition, and the practical effect, as Keen<sup>1</sup> has observed, is to lengthen the chest by one rib. The upward displacement of structures depends upon the extent of development of the anomalous rib and the nature of its fibrous attachments at the anterior end. The brachial plexus usually passes over the rib and symptoms frequently arise from pressure, particularly upon its lower cord. If the rib is short the arch of the subclavian artery may not be disturbed, but if the rib is long the artery may be carried over it or be caught and compressed between the anterior end of the rib and the tendinous insertion of the anterior scalene muscle. The symptoms in the latter case are primarily referable to the arterial occlusion, which is usually incomplete. Because of its lateral and posterior position the brachial plexus suffers interference much more frequently than the subclavian artery.

**Case Report.**—Hosp. No. A-04447: A. L., white, male, age 28, was admitted to St. Luke's Hospital, July 9, 1938, complaining of severe, steady pain in the fingers of the left hand, particularly the first, second, and third fingers, and a progressive sore on the end of the third finger of the left hand.

He stated that in December, 1937, approximately seven months before admission, while working out of doors, his hands became so cold that he was obliged to stop work. He soaked them in cold water and worked them until the circulation returned. With the return of circulation, there was a burning sensation which affected chiefly the left hand.

About two weeks later the patient accidentally inflicted a superficial scratch on the end of the left middle finger with a screw driver. This slight wound did not heal, but instead became surrounded by an area of redness and swelling. The lesion was treated with wet dressings. A small amount of pus drained out, leaving a hole which was larger than the original wound.

The condition did not heal and remained almost stationary in size until about three weeks before his admission to the hospital, when the finger became painful. The pain gradually extended to the other fingers of the hand and became so severe that the patient was unable to sleep. He was admitted to another hospital where studies revealed evidence of occlusion of the radial artery. After a course of treatment, which included the intravenous administration of 5 per cent sodium chloride solution, the symptoms were not relieved and the patient was discharged at his own request.

*Physical Examination* revealed nothing which appeared to be significant except the condition of the left hand and arm. The tips of the thumb, index and middle fingers showed dry, blackened, gangrenous areas of skin (Fig. 1). The tips of the fourth and fifth fingers were reddened and somewhat sensitive.

In the left supraclavicular region there was a hard, raised structure above which a

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pulsating vessel could be felt. The left arm showed slight general atrophy and the left hand was definitely cyanotic. The left brachial artery was palpable and pulsating to the junction of the middle and distal thirds of the humerus where pulsation ceased, and beyond that point the artery was felt as a hard, pulseless cord. Pulsation could not be detected in the left forearm, wrist, or hand. The maximal oscillations produced by the left brachial artery were 1 to 1.5 as compared with 4 to 5 for the right. The maximal left radio-ulnar oscillations were scarcely perceptible and were recorded as 0.5, whereas the maximal right radio-ulnar oscillations were 3.5. The temperature of the left hand and forearm was perceptibly lower than that of the right, and color returned slowly after compression. There were no focal areas of sensory or motor disturbance to indicate interference with components of the brachial plexus.



FIG. 1.—Photographs showing the gangrenous areas on thumb, index, and middle fingers.

*Laboratory Data.*—The blood and urine showed no significant changes. Roentgenograms of the cervical and upper thoracic spine showed an incompletely developed rib on each side. These appeared to be the first thoracic ribs but they were subsequently proven to be cervical. Each articulated with the first thoracic rib lateral to the scalene tubercle. The anomalous rib on the right side showed greater development than that on the left, but there were symptoms on the left side only. Believing that the left cervical rib was pressing against and partially occluding the subclavian artery, and was responsible for the changes observed in the left arm and hand, operation was undertaken.

*Operation.*—July 9, 1938: The region was exposed through an incision made above and approximately parallel to the left clavicle. The anterior end of the cervical rib formed a rounded, dense cartilaginous mass. The tendon of the scalenus anticus muscle was inserted normally into the first rib and passed very close to the cartilaginous end of the cervical rib. The subclavian artery lay in the narrow space between the scalenus anticus tendon, and the end of rib and was tightly compressed (Fig. 2). Immediately distal to the point of compression, the artery presented a fusiform aneurysmal dilatation

of the type which has been frequently observed after the prolonged constriction of an artery. The dilated portion was approximately twice the diameter of the artery above and below. The components of the brachial plexus, lying posterior and lateral to the artery, passed over the cervical rib lateral to the position of the artery and apparently suffered no interference.

The tendon of the scalenus anticus was severed near its attachment. This appeared to completely release the artery which immediately assumed a more medial position. The cartilaginous mass representing the anterior end of the cervical rib was removed by means of a rongeur, although this did not appear to be really necessary.

*Subsequent Course.*—Following operation, relief was immediate and almost complete so far as pain was concerned. There was no immediate return of the radial pulse. Oscillometric readings showed slight improvement, but the objective changes were not commensurate with the subjective relief. The gangrenous processes at the tips of the fingers slowly resolved and healed after sequestration of portions of the terminal phalanges of the index and middle fingers. Nearly six months were required for complete healing. There was gradual improvement in function and in the circulation of the hand and forearm but pulsation at the wrist did not reappear.

The patient was almost free from pain until April, 1939, nine months after operation, when he began to experience some discomfort in the region of the left shoulder girdle. At first mild, the discomfort gradually increased to a persistent aching pain which radiated along the medial surface of the arm, forearm, and hand. It became apparent that the brachial plexus had become involved and, on July 28, 1939, the rib was resected. It was found that the portion of rib removed at the first operation had partially regenerated and there was new bone and scar sufficient to compress the brachial plexus against the clavicle. The aneurysmal dilatation of the subclavian artery, observed at the first operation, had almost disappeared and the vessel at this point was of approximately normal caliber. The painful symptoms subsided after ablation of the rib and, when the patient was last examined, November 28, 1939, five months after the second operation, there was some residual weakness but no pain.

**COMMENT.**—The chief interest of this case is in the vascular changes, particularly the formation of an aneurysm distal to the point of compression, the apparent obliteration of the artery at a considerable distance peripheral to the site of partial occlusion, and the onset of gangrene in the finger tips.

**DISCUSSION.**—It is noteworthy that nearly all dilatations of the subclavian artery associated with cervical rib have been distal to the point of interference. Baumgartner,<sup>2</sup> *et al.*, and Flint<sup>3</sup> have reported cases in which the aneurysm was in direct contact with the sharp edge of a cervical rib. Attempts to explain the dilation of a vessel which occurs beyond a point of

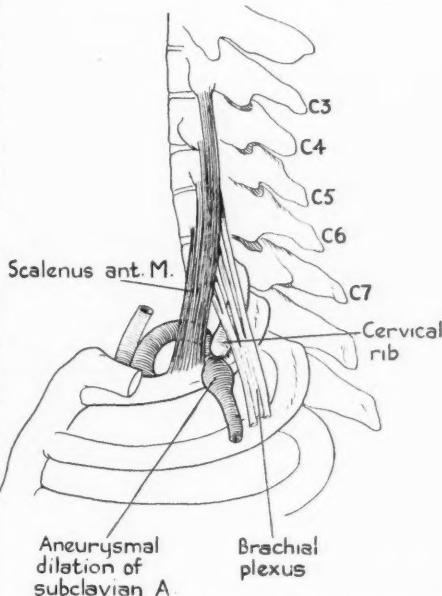


FIG. 2.—Diagrammatic sketch showing the brachial plexus passing over the cervical rib; the subclavian artery compressed between the anterior end of the rib and the tendon of anterior scalene muscle; and the fusiform aneurysm distal to the point of compression.

constriction have not been entirely satisfactory. Suggestions which have been offered are: Slowing of the blood stream with a resulting increase of lateral pressure; limitation of blood supply to the vessel wall through interference with the *vasa vasorum*; and trophic changes in the vascular structure due to paralysis of the sympathetic nerve supply.

In making a study directed toward finding the cause of dilation of the artery distal to the point of compression Halsted and Reid<sup>4</sup> reviewed 716 cases of cervical rib, taken mostly from the literature. Of this number, 191 were autopsy observations or museum specimens and the remaining 525 were clinical cases. Three hundred sixty of the clinical cases presented symptoms of pressure; 235 had nerve symptoms alone; 106 had nerve and vascular symptoms; and 19, or 5.3 per cent, had only vascular symptoms. In the 125 cases with symptoms which were interpreted as vascular, there were 27 in which a fusiform, aneurysmal, or cylindrical dilatation was observed. In the majority of these the disturbance of circulation was severe, and six cases had gangrene of the fingers.

In a more recent review of 554 cases of cervical rib, collected from the literature, Jacobsohn<sup>5</sup> found six cases with gangrene. A number of single cases with varying degrees of gangrene have been reported; among them may be mentioned those of Pasini,<sup>6</sup> Otto,<sup>7</sup> Langeron and Desbonnets,<sup>8</sup> Lenner,<sup>9</sup> and Baumgartner.<sup>2</sup> Two of the cases described by Adson and Coffey<sup>10</sup> had gangrenous changes of the finger tips.

The nature of the vascular lesions and their manner of production are matters which have interested a number of observers. The factor of direct pressure by the anomalous rib has long been recognized, and Adson<sup>10</sup> has called attention to the anterior scalene muscle as an important part of the pressure mechanism. The probable effects of disturbed innervation of the blood vessels have also been considered.

The vascular manifestations associated with cervical rib can hardly be explained on a basis of simple constriction or compression. Todd<sup>11</sup> minimized the importance of direct damage to the subclavian artery and came to the conclusion that the vascular symptoms occurring in cases of cervical rib are not mechanical in origin, but are trophic in character and are caused by paralysis of the sympathetic fibers passing to the vessels. It has, furthermore, been shown that grave vascular complications may occur even when the anatomic relations of the cervical rib are such that it impinges only on the brachial plexus and not upon the subclavian artery.<sup>12, 13</sup>

Leriche<sup>14</sup> also has stressed the importance of disturbed vasomotor function in accounting for the vascular phenomena. On the basis of his experience, he apparently believes that functional vasoconstriction, repeated with sufficient frequency, eventually leads to a true anatomic endarteritis which may persist after removal of the rib and develop on its own account.

In the case herewith reported, Leriche's theory was supported to the extent that the distal portion of the brachial artery and the radial artery were pulseless and apparently obliterated. Pulsation did not return after

liberation of the subclavian artery. There was, however, a definite improvement of circulation with healing of the gangrenous areas of the fingers and an almost complete symptomatic relief which lasted until evidence of pressure upon the brachial plexus appeared nine months later.

With respect to treatment in this case, the severing of the scalenus anticus tendon from its insertion on the first rib appeared to liberate the subclavian artery completely. It appears, in retrospect, that the cervical rib should have been entirely removed at the same time or not disturbed at all. The partial removal was followed by an excessive regeneration, with encroachment upon the brachial plexus and the development of symptoms referable to pressure upon elements of the plexus.

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## PULMONARY EMBOLISM

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PULMONARY EMBOLISM is common enough to keep the surgeon worried, uncommon enough to give him a false sense of security, and erratic enough in its incidence to bolster his faith in any method of preventive treatment. Sudden death from pulmonary embolism following an uneventful recovery from an operation, an injury, or an obstetric delivery is a tragedy that is not soon forgotten. More frequent, less spectacular, but nonetheless disturbing, is pulmonary infarction from a sublethal embolus. Besides these two groups of cases there are many patients who for months or years are incapacitated with thrombophlebitis of one or both legs. That the problem exists no one will question.

*Incidence.*—Wilson,<sup>1</sup> Patey,<sup>2</sup> Nettleblad,<sup>3</sup> Mason,<sup>4</sup> Bumzel,<sup>5</sup> Wharton and Pierson,<sup>6</sup> Dougal,<sup>7</sup> Murray and Best,<sup>8</sup> and Cleland and Barlow<sup>9</sup> inform us that fatal embolism follows 0.1 to 7.5 per cent of surgical operations and that postoperative thrombosis affects 1.0 to 7.5 per cent of surgical patients. The discrepancies in reported percentages are due partly to variations in the frequency of thrombosis after certain operations and injuries and partly to the interpretation of findings by the observer. Wharton and Pierson<sup>6</sup> reported that 40 per cent of the cases diagnosed as pleurisy and 12 per cent of those diagnosed as bronchopneumonia or pneumonia had been in reality instances of pulmonary infarction, and hence due to pulmonary embolism.

*Etiology.*—As embolism is usually a sequela of thrombosis any discussion of the etiology of pulmonary embolism must be primarily a consideration of venous thrombosis.

It is difficult in a study of the causes of thrombosis to decide what are etiologic and what are contributing factors. The following summary, not necessarily complete in detail, includes those conditions which have received most consideration:

- (1) Retarded circulation due to:
  - (a) Cardiac weakness
  - (b) Shallow respiration
  - (c) Inactivity
  - (d) Position
  - (e) Low blood pressure
  - (f) Increased intra-abdominal pressure

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- (2) Altered metabolism due to:
  - (a) Dehydration
  - (b) Low food intake
  - (c) Drugs
- (3) Blood changes affecting the:
  - (a) Platelets
  - (b) Clotting mechanism
  - (c) Chemistry
- (4) Tissue trauma
- (5) Infection
- (6) Vessel wall changes
- (7) Obesity
- (8) Age

*Discussion.*—Virchow<sup>10</sup> is often quoted as the first to consider retarded circulation as an important cause of thrombosis. Welch,<sup>11</sup> in 1899, in a very comprehensive review of thrombosis and embolism, stressed the importance of enfeebled circulation, but added that some other factor such as increase in the platelets, or a change in the composition of the blood might be important. He also discussed what Aschoff later demonstrated—that fibrin coagulation is not the first stage in thrombus formation. Aschoff<sup>12</sup> described white or static thrombi which are laid down on the wall of the vessel and consist of platelets and leukocytes. To this white thrombus the red thrombus consisting of the elements of coagulation is later attached. “The white thrombus is the determining and peculiar factor in the whole process: the red thrombi are only, so to speak, incidental, the first stage is the erection of a morphologic structure by a process of agglutination. Fibrin ferment is obtained from the agglutinated elements and cements them together by coagulation.” The original process has nothing to do with the coagulability of the blood but rather with that factor which allows the platelets and leukocytes to accumulate. A reproduction from his lecture illustrates his conception of how the change in the rate of flow and the eddies in the blood stream are conducive to the deposition of blood elements on the venous walls (Fig. 1). In discussing John Hunter’s observation that blood will not coagulate in a segment of vein tied off, Aschoff says that for intravascular clotting not complete stagnation but retardation of the blood flow is necessary to allow the accumulation of platelets.

Belt<sup>13</sup> states that pulmonary embolism, usually regarded as a postoperative complication, is more often associated with medical than surgical cases. From the Department of Pathology of the Toronto General Hospital, he reports pulmonary emboli in 10 per cent of 567 autopsies. Of these 56 cases, 37 were considered the immediate cause of death and only 11 had undergone operative treatment. He further observed that there was a history of some cardiac impairment in 49 of the 56 cases of embolism. He concludes that retardation of blood flow is the important factor in intravenous clotting. He found no infection in the clots and no microscopic changes in the intima of the veins

in which the thrombi developed. Henderson,<sup>14</sup> likewise, found that cardiovascular disease was the predominant illness in one-half of the nonsurgical cases of embolism.

From the studies of Blumgart and Weiss,<sup>15</sup> on the rate of blood flow, we learn that the arm-to-arm circulation in normal male individuals averages 18 seconds. In compensated cardiovascular disease the circulation time is 24 seconds, and in decompensated individuals 38 seconds. He states: "In general, the degree of cardiac decompensation at the time of the test was closely related to the degree of retardation of the velocity of the blood flow."

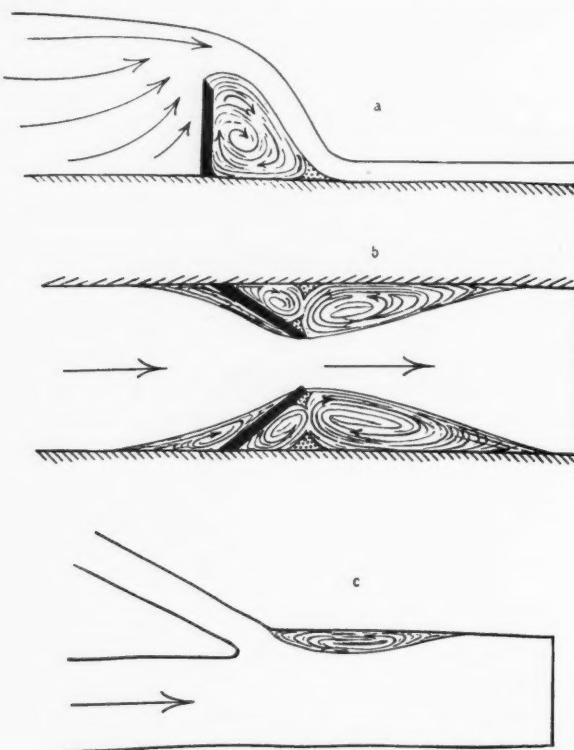


FIG. 1.—Diagrams showing (a) eddy formation behind a weir; (b) eddy formation in front of, behind and beneath obliquely placed weirs; (c) eddy formed at the point of junction of two streams of unequal size. (From Aschoff: Thrombose und Sandbankbildung. Ziegler's Beitr., 52, 209, 1912.)

Respiration is an important accessory factor in aiding the circulation (Howell<sup>16</sup> and Wiggers<sup>17</sup>). The negative intrathoracic pressure produced with each inspiration tends to aspirate the blood into the large veins of the thorax. During long or forced expiration the large veins become distended—easily observed in the external jugulars—and during inspiration they collapse quickly. Keith<sup>18</sup> states that emptying of the "venous cistern" of the abdomen and pelvis is aided by respiratory movements and muscle contractions. It must follow, then, that the return flow of venous blood is hampered when respiration is shallow as it is during severe illnesses and following abdominal operations.

Patey<sup>2</sup> pointed out that the normal variations in intra-abdominal pressure due to respiration are an important mechanism in aiding the return flow of blood.

The inactivity of bed rest, which is of necessity enforced upon each sick person, adds to the tendency toward venous stasis. In McCartney's<sup>19</sup> report of 73 cases of pulmonary embolism there were 15 strictly posttraumatic cases, 12 of which had lower extremity fractures and all of which were confined to bed. When the muscles of the legs and abdomen are inactive there is little alteration in the rate of blood flow in the pelvic and femoral veins. Thrombi practically never form in the axillary veins of postoperative patients. The reason for this, it is assumed, is that the beginning of any accumulation of platelets is prevented, or is promptly swept out, before a thrombus can form, by frequent alterations in the rate of blood flow produced by muscular contractions and elevation of the arms. Thrombosis and embolism are relatively common in fracture patients confined to bed in plaster encasements, especially those with fracture of the neck of the femur, but it is rare in ambulatory patients with arm, leg, shoulder, or spine fractures in encasements. Both groups are free from demonstrable infection. The amount of tissue trauma is the same in each. The importance of inactivity and position as factors in thrombosis looms large. With the lowering of blood pressure the rate of blood flow correspondingly falls. This affords an opportunity for the fixed elements of the blood to settle out. Walters<sup>20</sup> reported an average drop in blood pressure of 30 Mm.Hg. in postoperative patients.

Increased intra-abdominal pressure due to ileus, meteorism, and intestinal stasis follows practically all abdominal and many extra-abdominal operations. In abdominal distention of any degree pressure transferred against the inferior vena cava and the iliac veins hinders the normal return flow of blood from the legs.

The metabolism of the postoperative patient is profoundly altered. There may be psychic depression from the fear of surgery, toxemia from anesthesia and trauma, and shock from the loss of blood. Withholding preoperative fluids, sweating, vomiting and blood loss contribute to dehydration with consequent increase in the fixed elements of the blood. Inadequate food and inactivity lower the metabolism. Sedatives such as morphine and barbituric acid derivatives depress it still further.

Ever since the importance of the platelets was pointed out by Welch and Aschoff they have been studied vigorously. Hueck,<sup>21</sup> and Dawbarn, Earlam, and Evans<sup>22</sup> found a platelet rise from the sixth to the tenth postoperative day; the more extensive the operation the greater the rise in the platelet count. Wells<sup>23</sup> says that numerous studies on the relationship of the platelets and disease conditions have indicated a certain parallelism between their numbers and the tendency to coagulation observed in various disease conditions. On the contrary, Allen<sup>24</sup> found no uniform or significant variations in the platelet count in postoperative patients. Armitage, Pickering, and Mathur<sup>25</sup> add that the complete disintegration of blood platelets, produced with saponin, neither

produces intravascular clotting nor hastens the coagulation of normal blood which has been shed into paraffined vessels.

The mechanism of blood coagulation has long been fairly well known. The search is for those factors which will inhibit this mechanism within the vessels. Blood is a "streaming suspension" and anything which thickens the solution and slows its progress would seem to be of importance on the basis of pure mechanics in initiating the process. Earlam<sup>22</sup> hinted at the possibility of some coagulation inhibiting factor in the walls of the vessels themselves. Some writers have surmised that individual idiosyncrasies toward coagulation are of importance. Bancroft and his coworkers<sup>26</sup> are attempting by means of a plasma clotting test to seek out those patients who are susceptible to thrombosis. They divide all patients into three groups: Those with a tendency to bleed; those with normal clotting time; and those with a tendency to clot. The last group constitutes 12 per cent of patients.

Changes in the blood chemistry of postoperative patients are in general those found in cases of dehydration. A rise in the urea content of the blood has been demonstrated. Duval and Binet<sup>27</sup> stressed the importance of polypeptides as an important factor in pulmonary complications. Homans<sup>28</sup> sums up his view with this statement: "Blood chemistry, except for dehydration, is not a factor in thrombosis."

The release of tissue extracts—"tissue juices"—into the circulation by trauma has long been an attractive theory of thrombosis and is favored by Mason<sup>4</sup> who says: "The potency of such an extract has not been fully appreciated, for it requires only 0.003 Gm. of lung tissue extract to produce complete intravascular coagulation throughout a rabbit." Portal thrombosis following operations on the gallbladder, stomach and intestines is rarely observed, even though the portal vein is flooded with tissue extracts. Patey<sup>29</sup> injected tissue extract into the peritoneal cavity of dogs and found no subsequent thrombosis. If tissue extracts in the circulation were of great importance, thrombosis should extend from the site of operation, but actually the site of operation has little to do with the point at which thrombosis begins. Radical breast operations, which are very traumatic, are rarely followed by thrombosis while operations in the pelvis, especially prostatectomies, more commonly are. In patients with cardiac decompensation there is no greater release of thrombokinase, if any, than in other correspondingly ill patients and yet the former, as pointed out by Belt, have thrombosis far more frequently.

Over 100 years ago, Cruveilhier<sup>30</sup> became the chief exponent of the infection theory of thrombosis. He regarded the inflammatory changes in the vein as primary and the clotting of the blood as a secondary factor. Rosenow<sup>31</sup> isolated a diplostreptococcus from thrombi. Whether the organism was the cause or whether it lodged there after the thrombus had formed remains a question. Lockhart-Mummery<sup>32</sup> states, rather definitely, that he does not believe sepsis is the cause of pulmonary embolism. Repeated observations indicate that "clean" operations are more apt to be followed by fatal embolism than those complicated by infection. Sudden, fatal embolism strikes without

warning the patient who has made an uneventful postoperative recovery, while nonfatal and repeated pulmonary emboli more commonly follow clinically recognizable thrombophlebitis. If infection is an important cause of thrombosis why is the incidence of thrombosis and embolism greater, as it is, following fracture of the neck of the femur than following operations for suppurative appendicitis? Why should bacteremia cause thrombosis of the pelvic and femoral veins and not of the axillary? Furthermore, why should it pick out the left leg more commonly than the right?

Vessel wall changes beneath thrombi are conspicuous by their absence. Aschoff, Welch and Belt found no gross or microscopic changes in the walls of the vein beneath a simple thrombus. If pathologic alterations in the vessel walls were of any consequence, thrombosis should be frequent in the arterial trunks where vessel changes are commonly extensive and rare in veins which show few if any changes. The opposite is true. After an exhaustive postmortem study of fatal embolism Patey<sup>29</sup> concludes: "The veins in these subjects are exasperatingly normal."

Snell<sup>33</sup> called attention to the fact that the obese patient is more subject to embolism than the patient of average weight.

The average age of cases of thrombophlebitis is about 50 years, although it is not uncommon in the twenties.

*Prevention.*—During the past decade, most of the efforts toward the prevention of pulmonary embolism have been directed toward combating venous stasis.

Krecke,<sup>34</sup> in 1910, advised deep breaths for postoperative patients, and active and passive movements of the legs and massage.

Pool,<sup>35</sup> in 1913, developed a rather elaborate system of exercises for the arms, legs and head beginning on the third postoperative day. He also advised deep breathing exercises. No ill effects were observed following these procedures.

Blair Bell<sup>36</sup> states that with the adoption, in 1916, of systematic exercises accompanied by deep breathing, the Gynecologic Service at the Royal Infirmary had changed from the head of the list in both number and percentage of deaths to the bottom of the list.

Walters,<sup>20a</sup> in 1927, advised thyroid extract postoperatively to combat stasis and low blood pressure, and thereby reduced the incidence of pulmonary embolism from 0.34 to 0.09 per cent. He combined with this treatment movement of the arms and legs and frequent turning.

Decourcy<sup>37</sup> said: "I am one of those that believe that venous stasis is the most essential factor in the etiology of postoperative embolism." To combat stasis he places his patients in a reverse Fowler position by elevating the foot of the bed six inches. Schmid,<sup>38</sup> likewise, advises that the foot of the bed be raised 25 cm. immediately after operation and be left there four or five days.

Payr<sup>39</sup> obtained leg action by urging patients to work a wooden roller placed at the foot of the bed.

Gamble<sup>40</sup> has a bicycle-like device which patients are asked to "wheel" in bed. He also advises carbon dioxide inhalations the first postoperative day and deep breathing exercises thereafter.

Patey<sup>41</sup> recently suggested postoperative elevation of the head so that patients developing a thrombophlebitis might develop an extensive thrombus which would stick.

Barnes<sup>42</sup> emphasizes the importance of accelerating the return flow of blood from the lower extremities. He reports that one of the surgical services at the Mayo Clinic has adopted the following regimen: The Trendelenburg position for the first 24 hours after operation; carbon dioxide inhalations several times day and night during the first 48 hours; and deep breathing, active and passive exercises and massage of the legs until the patient is out of bed.

Bancroft<sup>26</sup> administers sodium thiosulphate to that group of patients whose plasma clotting index is high. He advises exercise as well.

Murray and Best<sup>8</sup> have recently advanced the possibilities of heparin as an anticoagulant for postoperative patients. It has been proven effective in blood vessel surgery. To give all surgical patients continuous heparin solutions intravenously for a number of days postoperatively is obviously difficult and at present economically impossible. If Bancroft's plasma clotting index will successfully pick out those few patients with tendencies to thrombosis, heparin may become a valuable addition to the armamentarium for combating postoperative pulmonary embolism.

From the above review it is apparent that the general trend of medical opinion has been toward support of venous stasis as the primary contributing factor in thrombosis and embolism. Most men agree that activity is essential for postoperative patients, but few have followed through with a definite scheme of exercises easy of accomplishment.

*Clinical.*—Believing that deep inspiration, leg elevation and muscular contraction will assist in sweeping out the pelvic and femoral veins, it was decided, in 1928, to adopt postoperative exercises routinely whenever possible. The following order, taking effect the morning after operation, was written for patients above 12 years of age. (The few exceptions were those seriously ill patients who were unable to carry them out and those who, it was thought, should conserve their strength.) *Have the patient take 15 deep breaths morning and evening and with each deep breath actively flex the legs.* It was concluded from experiments on dogs (to be reported later) that the combination of a deep breath with *active* flexion of the legs would be most effective; the deep breathing tending to aspirate the blood from the pelvic basin, contraction of the leg muscles squeezing the blood into the veins and elevation of the knees making the blood run out of the femoral veins by gravity. The choice of 15 deep breaths and leg flexions and their repetition twice a day was entirely arbitrary.

The amount and type of postoperative activity are too frequently left to the discretion and memory of the floor nurse. It is necessary to explain to the

nurse in charge, and frequently to the patient, how the above order is to be carried out. If the postoperative exercises are of value—and most surgeons believe they are—the necessity of having them carried out routinely by *written order* is apparent.

*Results.*—I hesitate to write the following sentence because pure coincidence so often leads us astray in evaluating therapeutic procedures. In no case during the past 11 years, during which period this regimen has been carried out, has there been a case of pulmonary embolism or thrombophlebitis. During this period, 518 adult patients underwent major surgical procedures and carried out the above breathing and leg exercises. The operations consisted of appendicectomies, cholecystectomies, common duct explorations, gastro-interostomies, intestinal obstructions, colon resections, exploratory celiotomies, herniotomies (inguinal and ventral), thyroidectomies, radical breast amputations, etc. Operations upon children under 13 years of age, minor cases such as hemorrhoidectomies, benign breast tumors and minor infections—in fact, all cases requiring a short hospital stay and only partial restriction of activity—are not included.

While the series of cases is small it assumes some importance when it is contrasted with the group of patients who served as controls. In this group were 95 patients with fractures of the leg, thigh, hip, pelvis or spine. All were confined to bed and completely inactive in leg or body encasements, or traction. Five cases of thrombophlebitis developed, three of which were followed by nonfatal pulmonary emboli. They are briefly reviewed:

#### ABBREVIATED CASE REPORTS

**Case 1.**—Mrs. W., age 33, developed extensive thrombophlebitis in the left femoral vein 14 days after fracture dislocation of the right sacro-iliac joint. Slow resorption followed but swelling of the leg persisted for four years.

**Case 2.**—Mr. H., age 65, was confined to bed with multiple bruises and a fracture of the external condyle of the left tibia which was immobilized in a plaster encasement from toes to groin. On the twenty-first day after injury, thrombophlebitis involved the left femoral and iliac veins causing extensive edema of the entire leg, groin and left half of the abdominal wall. Pulmonary infarction of the left lower lobe followed a few days later but cleared spontaneously.

**Case 3.**—Mrs. C., age 67, immobilized in a Whitman abduction spica for fracture of the neck of the left femur, had an infarct of the lower lobe of the right lung eight days after the spica was applied. Thrombophlebitis did not manifest itself until five days later, when swelling of both legs and the pelvis became so marked that the spica had to be split. The pulmonary infarction cleared spontaneously, after a very critical period, under conservative treatment. Swelling of both legs persisted for months. The fracture healed.

**Case 4.**—Mr. E., age 42, developed a very mild thrombophlebitis in the left leg following open reduction of a fracture of the patella. Two minor pulmonary infarctions, one associated with expectoration of blood, occurred after the patient had been discharged from the hospital.

**Case 5.**—Mr. B., age 31, had a severe fracture dislocation of the first lumbar vertebra which completely severed the spinal cord. He died six days after injury. Although there were no clinical signs of thrombophlebitis during life, at autopsy a large white and red thrombus was found in the right iliac vein and one embolus in the lung.

## RÉSUMÉ

(1) From a review of medical literature, and from my experience, stasis is one of the most important causes of venous thrombosis.

(2) It appears that routine breathing and leg exercises are of value in the prevention of postoperative thrombosis and embolism. Only years of experience with many cases can finally prove the value of this procedure. I have been able to detect no ill effects from it. Certainly, the exercised patients feel less weakened when they get out of bed than those who have been inactive.

(3) No clinically recognizable thrombosis or embolism occurred in 518 patients who, postoperatively, carried out these exercises.

(4) Five cases of thrombophlebitis, three of which were associated with nonfatal pulmonary embolism, occurred in the control group of 95 patients with fractures which required complete immobilization.

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## THE INFLUENCE OF CONGESTION UPON TUBERCULOSIS IN THE LUNG OF THE DOG

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IN A previous communication by Hyndman and Landt,<sup>1</sup> it was stated that no reference could be found concerning the effect of pulmonary vein ligation on pulmonary tuberculosis. The authors have since learned, however, that Walsh<sup>2</sup> suggested this as a therapeutic possibility in 1907. Walsh was stimulated by the fact that pulmonary tuberculosis and mitral insufficiency are infrequently associated. His work consisted in an attempt to ligate the pulmonary veins of dogs but the operative mortality was 100 per cent since no precaution was taken to prevent collapse of the lungs when the chest was opened.

In continuing our studies relative to congestion, we selected the dog because we expected to be provided with a progressive pulmonary lesion after endobronchial injection of virulent human tubercle bacilli. Although Fishberg<sup>3</sup> states that pigs, dogs, cats and sheep are not at all affected by human tubercle bacilli, Petit and Panisset<sup>4</sup> found that after endobronchial or trans-pulmonary injection into the lung of the dog and horse, a progressive lesion was initiated which remained limited to the lungs and which produced caseation and cavitation much the same as is found in the human. Opie<sup>5</sup> states that tuberculosis occurs with reasonable frequency among both domestic and wild Carnivores throughout the world, its incidence being 3 to 5 per cent in dogs and 0.5 to 2 per cent in cats. The lesion is a fibrocaseous mass with cavitation. Although our first animal died with overwhelming pulmonary tuberculosis three months after endobronchial injection of 0.2 cc. of milky suspension, there was only one other progressive lesion in a group of 24 dogs receiving 1 to 3 cc. of a milky suspension of bacilli into each lung.

In a previous experiment with guinea-pigs,<sup>1</sup> the authors stated a conviction that a progressive lesion is necessary in the controls, if a proper test of any therapeutic device is to be made. Upon this basis, we would have to eliminate the dog as a suitable experimental animal for our purposes. However, the difference in manner of healing of a tuberculous lesion in the congested as compared with the uncongested lung was so striking that we feel it worthy of publication. This obvious difference in the manner of healing applies only to those lesions produced by endobronchial administration of large doses of tubercle bacilli.

*Operative Procedure.*—All intrathoracic operative work was performed

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under positive pressure ether anesthesia, using the simple and effective apparatus described by Livingston and Hrdina.<sup>6</sup> Dogs of average size received 1 gr. of morphia intramuscularly one-half hour preceding anesthesia.

It was concluded that the left side was more suitable than the right for ligation of the pulmonary veins, as on the left the veins enter the hilus as three definite trunks, easily available for the passage of a ligature, while on the right, the trunks divide early into smaller branches and the branching is inconstant. Ligature of all of the veins on the left at one operation was concluded to be advisable and not in the least incompatible with life.

Through an incision three inches long in an interspace opposite the xiphoid process, a ligature of black silk was passed around each of the three pulmonary veins on the left and tied securely.

After ligating a vein, the lobe which is drained by that vein immediately assumes a brick-red color and there is a slight appearance of cyanosis in the unligated lobes. The cause of this phenomenon is obvious, but it illustrates that when dealing with congestion of the pulmonary circulation one is faced with factors that are different from those in other tissues, inasmuch as stagnant blood in the pulmonary circulation becomes saturated with oxygen rather than carbon dioxide. The effects of obstructed venous flow soon manifest themselves, however, for within 24 hours the affected lung becomes swollen, boggy, dark purple and nonair containing. The liver-like consistency appears not unlike that in the red hepatization of lobar pneumonia. Microscopically, the parenchyma presents a mass of closely packed red blood cells among which the alveolar outlines are greatly obscured. At this stage there is a small amount of thin, serosanguineous fluid in the pleural cavity and in the bronchi of the affected side.

After a month, it is very striking to see how the completely ligated lung has become restored. The visceral pleura becomes thickened but is adherent to only the line of incision. The interlobar pleural surfaces, however, become firmly adherent with considerable scar formation. Scar tissue is strikingly absent throughout the parenchyma. There is evidence of acute emphysema with rupture of alveolar walls, and this change occurs to some extent in the unoperated lung. Otherwise the operated lung is air containing and functioning.

## PART I

## ORGANISMS DISSEMINATED BY INTRAVASCULAR ADMINISTRATION

Fresh suspensions of tubercle bacilli in normal saline were made for each day's experimentation by shaking cultures of six weeks' growth with glass beads. The Gluckson human strain\* was used and subcultures made on glycerin gentian violet potato media.

**Exper. I.**, October 21, 1931.—Under positive pressure ether anesthesia, 0.2 cc. of a

\* We were provided with the Gluckson strain through the kindness of H. J. Corper.

milky suspension of bacilli diluted in 6 cc. normal saline was injected into the right ventricle of the heart. After five minutes the vein to the upper lobe of the left lung was ligated.

*November 6, 1931.*—Under anesthesia, the left chest was opened. No evidence of tuberculosis was seen on the surface of the entire left lung. The left upper lobe of the lung was adherent firmly to the middle lobe. There was no gross appearance of congestion.

*November 30, 1931.*—Forty days after inoculation, the animal was killed and presented no evidence of tuberculosis in the lungs, liver, spleen or kidneys.

**Exper. II, October 21, 1931.**—Same as Exper. I, except 0.1 cc. of suspension was used in 6 cc. saline and the vein to the left middle lobe was ligated.

*March 2, 1932.*—One hundred and thirty-two days after inoculation, the animal was killed and showed no evidence of tuberculosis in the lungs (microscopically) or grossly in the liver, spleen or kidneys. The left middle lobe was adherent to the upper and lower lobes. It was slightly contracted but on a cut-surface appeared almost as air containing as the upper and lower lobes.

**Exper. III, October 22, 1931.**—A small mongrel received 1 gr. of morphia. Two-tenths cc. of a milky suspension of bacilli diluted in 6 cc. normal saline was injected into the left femoral vein.

*March 21, 1932.*—One hundred and fifty days after inoculation the left chest was opened under anesthesia. No evidence of tuberculosis was seen on the surface of the left lung. All three veins to the left lung were ligated. The incision was closed and 3 cc. of a milky suspension of bacilli injected into the left femoral vein.

*April 21, 1932.*—Twenty-two days after ligation and second inoculation, the animal was killed. Miliary tubercles averaging 2 Mm. in diameter were rather evenly scattered over the pleural surfaces of both lungs. The parenchyma revealed no gross lesion. There was no appreciable difference in the number, size or microscopic character of the lesions on the two sides.

**Exper. IV, October 22, 1931.**—A small mongrel received 1 gr. of morphia. Two-tenths cc. of a milky suspension of bacilli diluted in 6 cc. normal saline was injected into the left femoral vein.

*December 22, 1931.*—Sixty days after inoculation the left chest was opened under anesthesia. No evidence of tuberculosis was seen on the surface of the left lung. All three veins were ligated.

*March 2, 1932.*—One hundred and thirty-one days after inoculation, animal was killed and revealed no tuberculosis (microscopically) in the lungs or grossly in the liver, spleen and kidneys.

**Exper. V, July 12, 1932.**—Two small mongrels received each 1 gr. of morphia. Three cc. of a milky suspension of bacilli were injected into the left femoral vein of each. One animal died in 41 days and the other in 44 days. Both revealed an overwhelming miliary seeding of the visceral pleura and enough involvement of the parenchyma to give the lung a "shotty" feel.

**SUMMARY.**—As much as 0.2 cc. of a milky suspension of bacilli injected into the right heart or femoral vein failed to produce evidence of tuberculosis in the lungs in 40 to 150 days.

In one dog, all left pulmonary veins were ligated and 3 cc. of a milky suspension injected into the femoral vein. After 22 days the pleura of both lungs was studded with miliary tubercles. There was no gross or microscopic difference in appearance of the tubercles on the two sides and they were approximately equal in number.

Two dogs received each 3 cc. of a milky suspension intravenously and died in 41 and 44 days with overwhelming miliary seeding. The visceral pleura was markedly studded but the parenchyma was much less involved.

CONCLUSIONS

- (1) Dogs are considerably resistant to human tubercle bacilli injected into the blood stream.
- (2) Pulmonary congestion appears to have no influence upon the number or pathologic character of tubercles which develop in the pleura, after intra-vascular injection (one dog).

PART II

ENDOBRONCHIAL ADMINISTRATION OF ORGANISMS

Dogs of average size received  $\frac{1}{2}$  to 1 gr. of morphia intramuscularly and in one-half hour an intraperitoneal injection of a 10 per cent aqueous solution

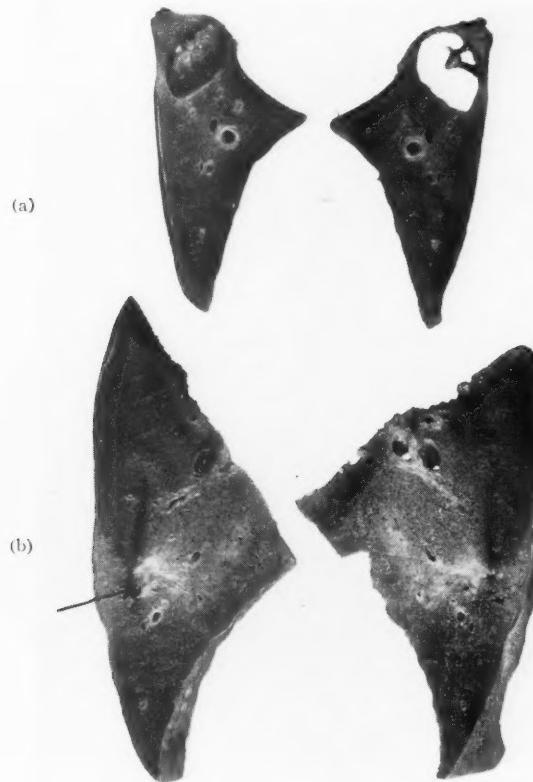


FIG. 1.—Dog No. 16: (a) Showing cavity with obliterated vessels in unoperated lung, middle lobe. (b) Showing scar formation in operated lung, lower lobe.

of sodium amyital (55 mg. per kilo of body weight). With the aid of a bronchoscope, a ureteral catheter was placed in a primary bronchus as far as it would go. A suspension of tubercle bacilli was then injected with the lung in a dependent position. The inoculum was followed by several syringes full

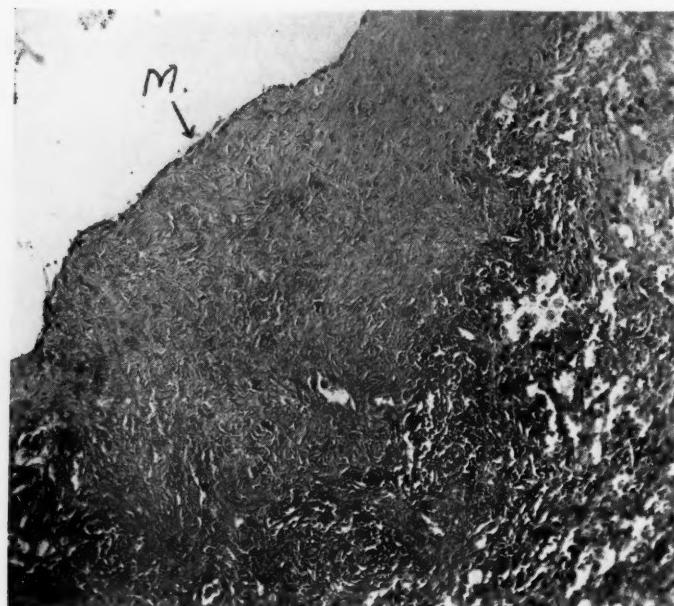


FIG. 1 (c).—Photomicrograph of section taken from (a). M. Margin of cavity.

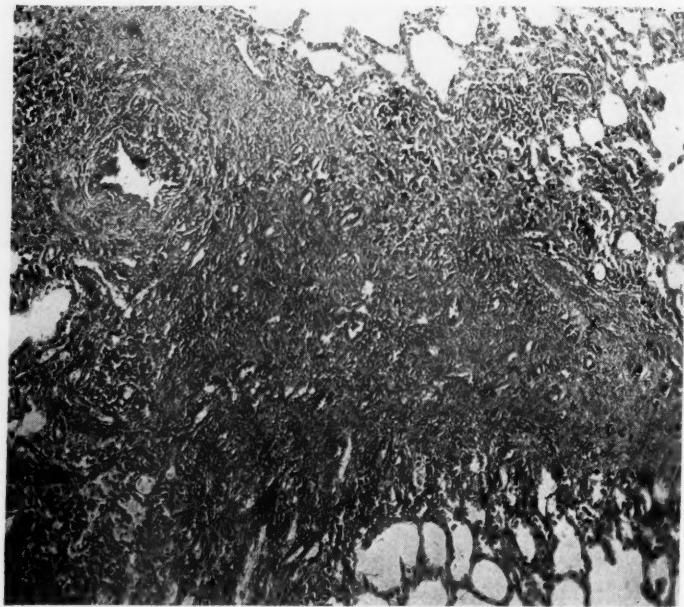


FIG. 1 (d).—Photomicrograph of section taken from lesion in (b). There is a greater degree of vascularization of the caseous tissue than in (c).

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of air to empty the catheter. The same dose was always injected in each side.

*Microscopic Appearance of Lesions.*—Lesions produced in this way revealed caseation with surrounding atelectasis and cellular infiltration. Endothelioid cells, small round cells and desquamated pigment containing alveolar cells filled alveolae. Giant cells were never seen.



FIG. 2.—Dog No. 21; (a) Showing cavity in unoperated lung, lower lobe. (b) Showing diffuse healing lesion without cavitation in operated lung, lower lobe.

The only microscopic difference of any possible significance that could be detected in the congested and the uncongested lungs is that in the former there seemed to be a greater tendency toward vascularization with no sharp transition between caseous and viable lung, and this was evident to a striking degree in only one animal. In the uncongested lung the caseous tissue was rather sharply delimited from viable tissue (Fig. 1).

### EXPERIMENTS

**Dog No. 16, February 25, 1932.**—One-half cc. milky suspension (Gluckson strain) deep into each main bronchus.

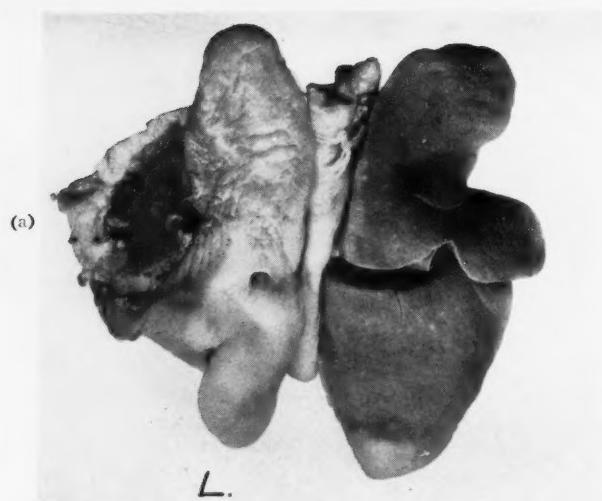


FIG. 3.—Dog No. 29: (a) Showing external appearance of lungs. Note the pleural thickening on the operated side (L). The shaggy portion was adherent to the line of incision in the parietal pleura. Large lesions may be seen in both lower lobes.

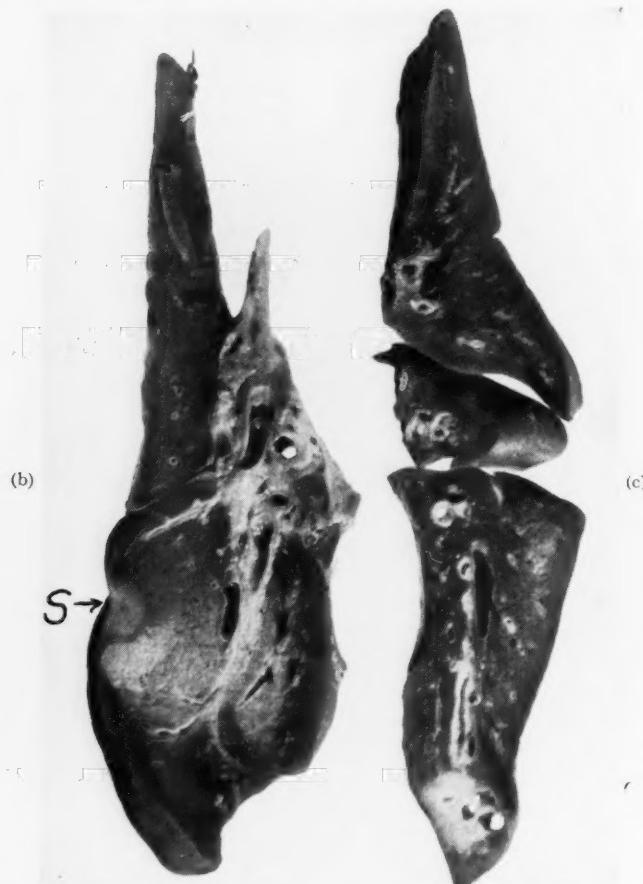


FIG. 3 (b).—Cut surface of operated lung showing a contracting scarred lesion (S) and a large caseating lesion without cavitation. (c) Cut surface of unoperated lung showing discrete caseating lesion in lower lobe with beginning cavitation.

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*March 21, 1932 (24 days).*—Left chest opened. Large caseous mass noted in lower lobe. All pulmonary veins ligated.

*July 5, 1932 (130 days).*—Animal killed. Right (unoperated) side, cavity found in middle lobe. Left (operated) side, scarred lesion found in lower lobe (Fig. 1).

**Dog No. 21, March 25, 1932.**—One-quarter cc. milky suspension deep into each main bronchus. After three hours, all pulmonary veins on left ligated.

*July 6, 1932 (104 days).*—Animal killed. Right (unoperated) side, cavity found in lower lobe. Left (operated) side, diffuse scarring in lower aspect of lower lobe (Fig. 2).

**Dog No. 29, July 21, 1932.**—One cc. milky suspension deep into each main bronchus.

*July 25, 1932 (four days).*—All left pulmonary veins ligated.



FIG. 4.—Dog No. 30: (a) External appearance of lungs showing multiple discrete lesions in the unoperated lung (R).

*September 7, 1932 (48 days).*—Animal killed. Right (unoperated) side, beginning cavitation in lower lobe. Left (operated) side, scarring and caseation without beginning cavitation in lower lobe (Fig. 3).

**Dog No. 30, July 21, 1932.**—One cc. milky suspension deep into each main bronchus.

*July 25, 1932 (four days).*—All left pulmonary veins ligated.

*September 7, 1932 (48 days).*—Animal killed (was emaciated and hind legs paralyzed). Right (unoperated) side, clear-cut disseminated lesions chiefly in lower lobe. Left (operated) side, more diffuse and less evident lesions in lower lobe (Fig. 4).

**Dog No. 31, July 21, 1932.**—One cc. milky suspension deep into each main bronchus.

*July 25, 1932 (four days).*—All left pulmonary veins ligated.

*September 7, 1932 (48 days).*—Animal killed. Lesions found in right accessory and left lower lobe. They did not differ greatly in appearance (Fig. 5).

**Dog A, January 11, 1933.**—All left pulmonary veins ligated.

*January 16, 1933 (five days).*—One cc. milky suspension (of a human culture from case of epididymitis) deep into each main bronchus.

*April 26, 1933 (100 days).*—Animal killed. Right (unoperated) side, cavity in lower lobe. Left (operated) side, diffuse inconspicuous lesion in lower lobe. Verified microscopically (Fig. 6).



FIG. 4 (b).—Cut surface of lungs showing discrete lesions in unoperated lung and more confluent but less evident lesions in the operated lung (L.).

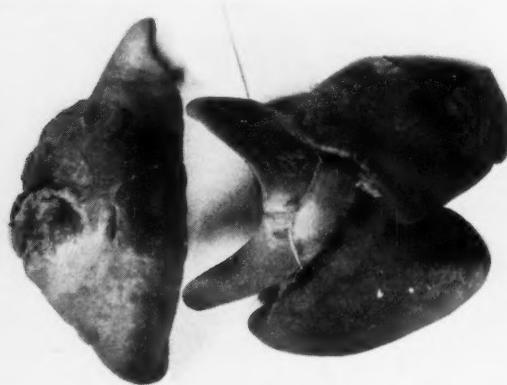


FIG. 5.—Dog No. 31: (a) External appearance of lungs showing lesions in right accessory and left lower lobes.

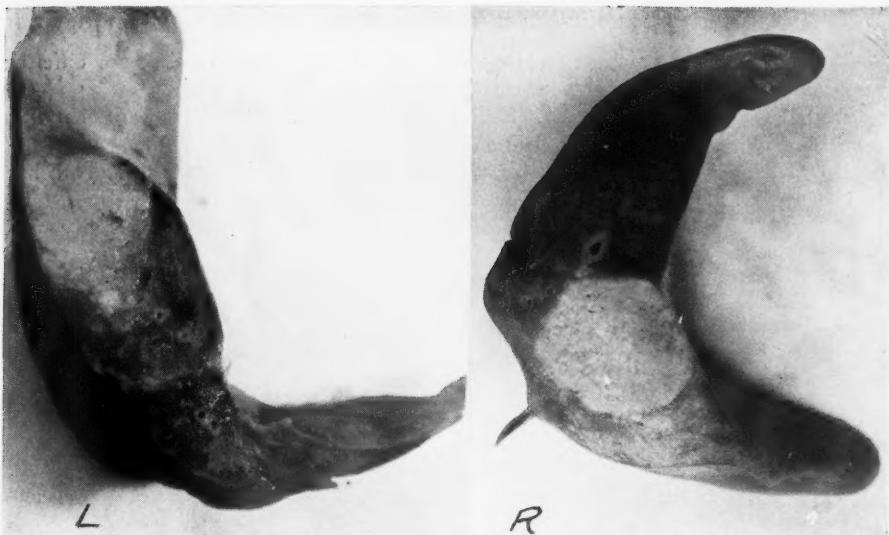


FIG. 5 (b).—Cut surface of lesions in operated lung (L) and unoperated lung (R). The lesions on the two sides do not differ greatly in appearance at this stage (48 days).



FIG. 6.—Dog A: (a) Mild, diffuse and inconspicuous lesion in operated lung, lower lobe. (b) Cavity with obliterated vessels in unoperated lung, lower lobe.

**Dogs B and C.**—Same as for Dog A. Lesion found in both lungs, not differing greatly on the two sides and without cavity formation.

**Dog D.**—Same as for Dog A. This animal died 83 days following injection with overwhelming caseating lesions on both sides.

**Dog E, January 16, 1933.**—One cc. milky suspension deep into each main bronchus.  
**January 31, 1933 (15 days).**—All left pulmonary veins ligated.

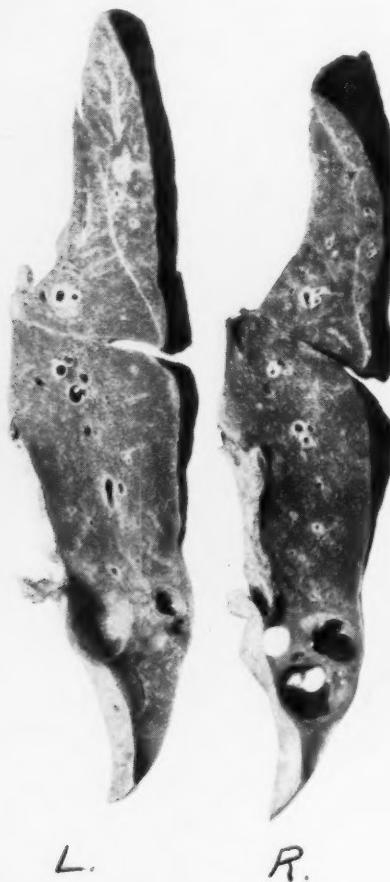


FIG. 7.—Dog E: Lesions in the lower lobes of both lungs; L, operated and R, unoperated.

*April 9, 1933 (83 days).*—Animal killed. Cavities in both lower lobes not differing greatly in appearance (Fig. 7).

**Dog F.**—Same as for Dog E. Killed 100 days after injection. Small lesions in both lungs not differing greatly in appearance and no cavities.

**Dog G, January 25, 1933.**—One and one-half cc. milky suspension deep into each main bronchus.

*April 26, 1933 (91 days).*—Animal killed. Beginning cavitation in caseous lesion in both lower lobes. Lesions did not differ in appearance (Fig. 8).

**SUMMARY.**—After endobronchial injections, lesions uniformly developed in the dependent parts of both lungs. After 48 days the lesions were well ad-

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vanced in the caseous stage. Cavitation was either just beginning or not present. At this stage, the lesion in the congested lung did not appear very different from that in the unoperated lung except in Dog No. 30. Here the lesions were scattered and appeared clean-cut and solitary on the unoperated side while on the congested side they were diffuse and more confluent.



FIG. 8.—Dog G: Equivalent lesions with beginning cavitation in the lower lobes of both lungs. The pulmonary veins were not ligated in this animal.

Ligation of pulmonary veins was delayed in two dogs, 15 and 24 days after inoculation. In the first of these, 83 days later, cavity containing lesions appeared much the same in both lower lobes. In the second, 130 days later, a cavity was present on the unoperated and a scarred lesion on the operated side.

In five dogs the veins were ligated within five days of inoculation. (In one of these the veins were ligated before inoculation.) One died after 83 days of overwhelming caseous lesions on both sides. Two, after 100 days, presented caseous but healing lesions without cavitation and not differing on

the two sides. Two dogs, after 100 and 104 days, presented a well formed cavity on the unoperated side and a scarred lesion on the operated side.

One unoperated dog presented beginning cavitation in equivalent lesions on the two sides 91 days after inoculation.

The only cavity that developed in a congested lung was in Dog E, in which the veins were ligated 15 days following inoculation. On the other hand cavities developed in six unoperated lungs in this series.

#### CONCLUSIONS

(1) The dog has a remarkable power of healing large endobronchial doses of human tubercle bacilli. Advanced caseous lesions appear in 48 days, and in 100 to 130 days only benign appearing cavities remain, as a rule.

(2) The manner in which equivalent lesions healed in the same dog differed notably in the congested and uncongested lungs.

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## PERSISTENT SPINAL FLUID FISTULA DUE TO FOREIGN BODY

ASSOCIATED WITH STAB WOUND OF THE HEART WITH RECOVERY

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REVIEW of the readily available American literature reveals only three references to cerebrospinal fluid leakage caused by the presence of a foreign body. Ball and Spurling<sup>1</sup> report an instance of a cerebrospinal fluid leak due to a fistula of the cisterna magna, caused by a stab wound in this region. This patient drained 17 days. On the twelfth day, a meningitis developed from which the patient recovered. Shawan<sup>2</sup> reports a case of stab wound of the neck followed by leakage of cerebrospinal fluid, but without cord damage. In this case, the causative knife blade was removed operatively and the patient recovered. Rand and Patterson,<sup>3</sup> in an extensive article on stab wounds of the spinal cord, report seven cases, only one of which showed drainage of cerebrospinal fluid and no case showed the presence of a foreign body. Owen<sup>4</sup> reports a case in which a foreign body was present but in which there was no fistula or cord injury resulting.

In the foreign literature, Orth,<sup>5</sup> and Mavrodi and Tzovaru<sup>6</sup> report cases of wounds of the spinal cord with the drainage of spinal fluid.

**Case Report.**—Hosp. No. 109558: E. N., colored, female, age 25, was admitted to the Harlem Hospital, August 8, 1938. She had been stabbed and slashed in the back of the neck, left face, left breast and left hand. She was cold, perspiring profusely and in severe collapse, complaining of inability to move her extremities.

**Physical Examination.**—The essential stab wounds showed a one-half inch vertical laceration at the level of the third cervical spinous process just to the right of the mid-line. There was a one-half inch laceration of the left breast in the lower outer quadrant, with the breast in the dependent position (Fig. 1). This was in the anterior axillary line at the level of the fifth rib. Five inches internal to this, at the margin of the sternum, there was tenderness on slight pressure. Blood pressure 60/32; temperature 97.8° F.; pulse imperceptible. Auscultation of the heart revealed only an occasional audible beat. She was immediately operated upon.

**Operation.**—Dr. David H. Smith: Under general anesthesia, a flap of skin, subcutaneous tissue and muscle, extending from the second to seventh rib was reflected (Fig. 1). The fourth and fifth costal cartilages and portions of the ribs were removed. The internal mammary artery was then ligated. The three-quarter inch vertical tear in the pericardium was enlarged to three and a half inches, exposing the heart. There was noted a one-half inch transverse laceration of the left ventricle situated one inch above the apex. This was oozing blood. The under surface of the heart opposite this wound presented a one-quarter inch subpericardial hemorrhage. The pericardial sac contained about 100 cc. of blood. The left pleural cavity contained about 300 cc. of blood. Three interrupted

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black silk sutures were used to approximate the wound of the anterior surface. These were left long and served as tractors, the heart not being manually handled. The heart was rotated by these sutures and a single silk suture used to bury the hemorrhagic area in the right ventricular wall. The pericardial wound was resutured leaving a gap of three-quarters of an inch for drainage into the left pleural cavity. The wound was closed in layers, the lung being sewn to the wound margins. A rubber dam drain was inserted just beneath the fat, at the lower angle of the wound.



FIG. 1.—Showing the operative incision and scar. Breast shows the stab wound.

After the start of the operation, the patient received 500 cc. of 5 per cent glucose in saline followed by a 500 cc. whole blood transfusion. A large bore needle was inserted into the left upper chest anteriorly in the second interspace to drain off excess air, and under water drainage was thus established. The operation consumed one hour and 15 minutes.

*Postoperative Course.*—The first postoperative day, the patient received another transfusion of 500 cc. The blood pressure rose to 118/70. She was able to move her limbs slightly. The pneumothorax reading was -1, 0.

The second postoperative day, oral sulfanilamide therapy was started and she received 30 gr. daily during the next 15 days. On the second day she received a 250 cc. transfusion and was also taking fluids by mouth.

On the third postoperative day, the patient exhibited a paresis of the entire right side of the body with an absence of sensation in the right arm. The neck was discharging

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a pale, yellow, opalescent fluid which was grossly similar to spinal fluid. During the first week, this fluid continued to discharge from the neck. Its reaction was alkaline, and contained sugar 52 mg., sodium chloride 660 mg. The laboratory reported that the tests would indicate that this fluid was spinal fluid but due to the presence of blood this could not be determined with absolute certainty.

By the fourth postoperative day, the drainage of this fluid was very profuse. Smear showed polymorphonuclear leukocytes and gram-negative Bacilli. Culture showed *B. coli*. On several subsequent occasions this fluid showed cultures of *B. coli*.

During the first week the temperature fluctuated between 101° and 102° F.

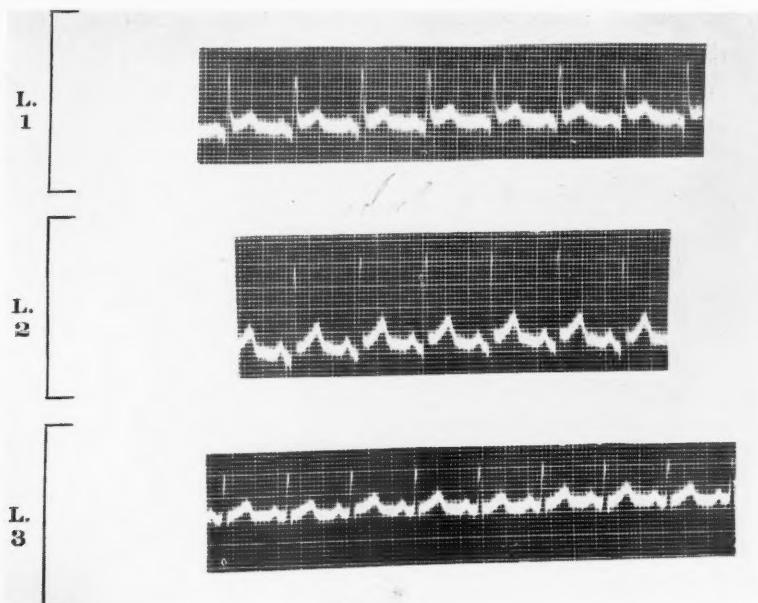


CHART 1.—The electrocardiogram made on the day following operation showing high ST take-off in Leads 1 and 2.

The electrocardiogram, the day following operation (Chart 1), showed high ST take-off in Leads 1 and 2, indicating coronary changes. One week later, the EKG showed sinus rhythm and no evidence of injury to the pericardium or myocardium (Chart 2). Two subsequent, weekly EKG's showed no abnormality, yet another, taken six weeks after the injury (Chart 3), showed in Lead 1, a prominent P wave and a slurred R wave. Leads 2 and 3 showed inverted T waves, indicating myocardial damage.

Roentgenologic examination of the chest immediately postoperative showed a pneumothorax on the left side with partial collapse of the lung.

Further progress was satisfactory except for a paresis of the right arm.

Spinal tap was first done two weeks after injury. The fluid was clear. The cell count was eight lymphocytes and the pressure 150 Mm. The tap was done because of headache and a persistently rigid neck. Roentgenograms of the cervical region, on several occasions, were unsatisfactory because of difficulty in getting the patient into good position.

Four weeks after operation, the patient was out of bed in a wheel chair. She was allowed up each day in the chair for the next ten days. At the expiration of this time, her progress was so marked that she was allowed to walk about ten feet. She then was returned to bed. Fifteen minutes later, she complained to the nurse that she was unable to move her arm or legs.

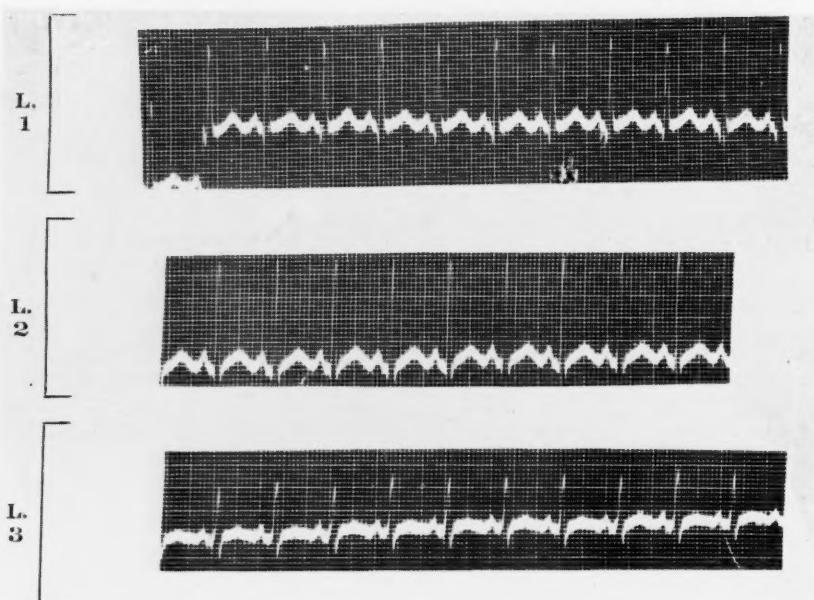


CHART 2.—An electrocardiogram made one week following operation.

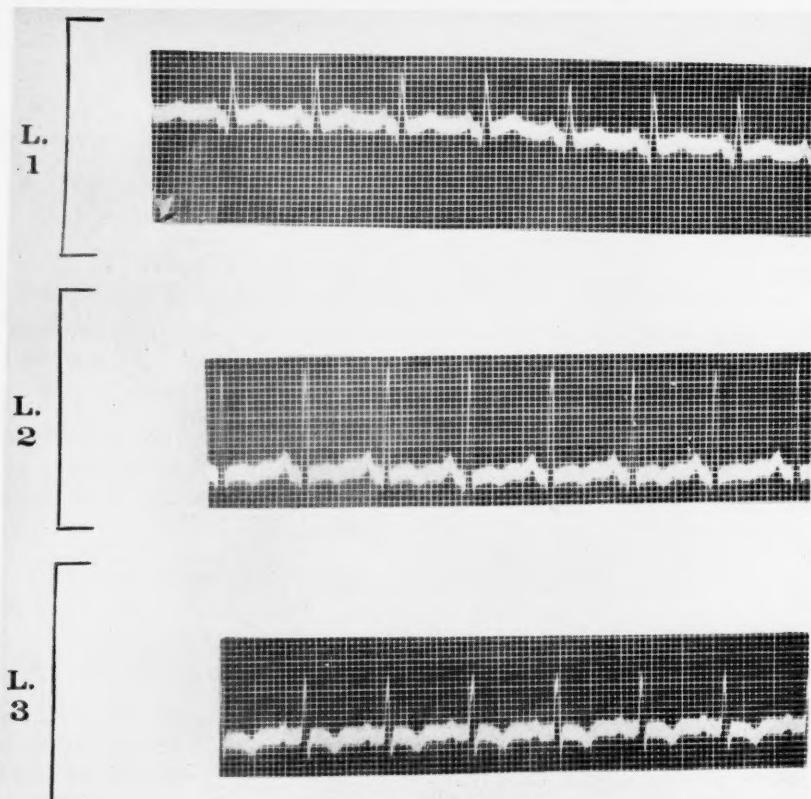


CHART 3.—An electrocardiogram made six weeks after injury; with Lead 1 showing prominent P and slurred R. Leads 2 and 3 show an inverted T wave.

## SPINAL FLUID FISTULA

Neurologic examination showed loss of sensation from the clavicles down. There was loss of sphincteric control (both urine and feces) and complete loss of motion of the extremities with the exception of the left arm, which was paretic. The right biceps reflex was absent. All other deep reflexes were hyperactive. There were bilateral ankle clonus and bilateral Babinski signs. Rigidity of the neck was marked. There was bilateral papilledema amounting to four diopters. It was felt there was a root

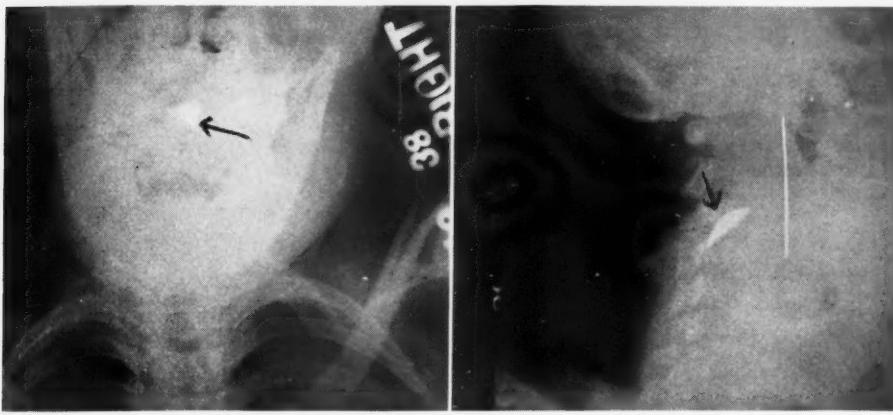


FIG. 2.—Roentgenograms showing (A) and (B) different aspects of the knife blade in the cervical cord.

lesion at C<sub>5</sub> or 6, right side. Spinal tap was again performed. The fluid was clear and showed five lymphocytes; pressure 415 Mm. Kahn negative. Colloidal gold showed no abnormality. The Queckenstedt was negative.

Because of the cord symptoms, the neck was again roentgenographed. A broken knife blade was visualized, apparently between the third and fourth cervical vertebrae (Fig. 2, A and B).

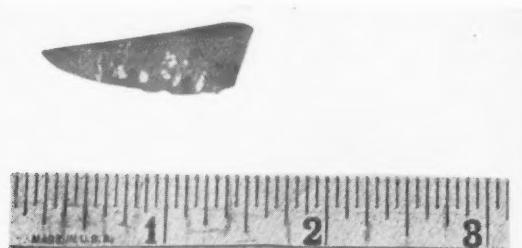


FIG. 3.—Photograph of knife blade extracted.

Forty-six days after the initial injury, the patient was reoperated upon. A midline, posterior cervical incision was made under local anesthesia (1 per cent novocain) and the tissues incised down to the bodies of the vertebrae. A sinus tract led down to the third cervical vertebra through which the spinal fluid had ceased to drain three weeks previously. After a tedious search, the knife blade was finally discovered, a distance of about one and one-quarter inches, between the bodies of the third and fourth cervical vertebrae, right side. It protruded about one-quarter inch into the spinal canal (Fig. 3). There was no leakage of spinal fluid. Culture of the tissues later showed *Staphylococcus albus*. The wound was lightly packed with iodoform gauze. The operation took one hour and 40 minutes.

Three days following this operation, muscle strength began to return. There was also a desire to urinate. But the papilledema did not subside.

Two months following this second operation, motor power of all the extremities was very good. However, there was occasional urinary incontinence and some difficulty in supporting the body weight. The thoracic incision had completely healed and there was no abnormal pulsation in the precordial area.

**COMMENT.**—(1) This case is unusual in that there was present a fistula of spinal fluid which drained from the open dura in the cervical portion of the canal for 25 days. And yet, even in the presence of a foreign body, infection of the meninges did not occur.

(2) Because meningitis commonly complicates spinal cord injuries of the above type, and because suppurative pericarditis is often the lethal factor following stab wounds of the heart, it is strongly recommended that sulf-anilamide be given these cases.

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## DUODENOJEJUNOSTOMY FOR CONGENITAL, INTRINSIC, TOTAL ATRESIA AT THE DUODENOJEJUNAL JUNCTION\*

SUCCESSFUL RESULT IN A THREE-DAY-OLD, ONE-MONTH-PREMATURE INFANT  
WEIGHING FOUR POUNDS TWO OUNCES

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CONGENITAL OBSTRUCTIONS of the upper intestinal tract have been recognized since Calder's<sup>1</sup> first report, in 1733, but apparently the diagnosis was usually overlooked or, if made, the treatment was unsuccessful, because, as late as 1922, Davis and Poynter<sup>2</sup> reported on 392 cases of congenital intestinal occlusions of all parts of the intestinal tract above the anus, collected from the literature, either autopsy or operative findings, with only two recoveries after entero-enterostomy—a mortality of nearly 99.5 per cent. The first recovery in a case of atresia of the lower ileum is credited to Fockens,<sup>3</sup> in 1911, and the second in a case of atresia of the second portion of the duodenum below the papilla to Ernst,<sup>4</sup> in 1916. They also showed that the condition is not exceptionally rare, because they estimated that it occurred about once in 20,000 infants, and that in 15 per cent the atresias are multiple and more or less beyond the aid of surgery. Quite a number of operative successes in high occlusions have been reported since Fockens' first case, notably by Ladd,<sup>5</sup> Morton and Jones,<sup>6</sup> and McIntosh and Donovan,<sup>7</sup> all of whom have reported on multiple experiences, with a large proportion of satisfactory results and a gradually increasing reduction of the postoperative death rate. Stenson<sup>8</sup> has also recently reported an operative success in a case of extrinsic duodenal atresia occurring in a premature twin. To these I wish to add the appended successful operative result in a case of intrinsic, total atresia at the duodenojejunal junction. As far as a rather careful search of the literature reveals, the patient is the youngest one—also taking into consideration his one month's prematurity—which has recovered.

**Case Report.**—E. H., white, male, age three days, was born March 29, 1938, at Lenox Hill Hospital. It was the first child and one month premature. Weight at birth four pounds 11 ounces. It did not retain any feedings and vomited bile-stained material from birth, and had passed only a few meconium stools. It became increasingly jaundiced and had lost nine ounces when first seen by the author in consultation with Dr. Jerome S. Leopold, April 1, 1938, when it was three days old.

**Physical Examination.**—The child was a very small, feeble, emaciated, deeply jaundiced, quite dehydrated infant weighing four pounds two ounces. The abdomen was somewhat distended. There was a decidedly dilated stomach, with visible gastric peristalsis, and an indefinite sausage-like mass could be palpated running obliquely from the right upper to the left lower quadrant. Roentgenologic examination of the alimentary

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tract showed a normal esophagus; a considerably dilated stomach with active peristalsis; a wide open pylorus; and a tremendously distended duodenum with a complete obstruction at what appeared to be the duodenojejunal junction. There was absolutely no passage of barium beyond the point of obstruction after three and one-half hours (Fig. 1). The blood count showed 170 per cent hemoglobin and 5,500,000 red blood cells—the result of the dehydration.

*Operation.*—April 1, 1938: Dr. DeWitt Stetten. Preoperative gastric lavage. Under

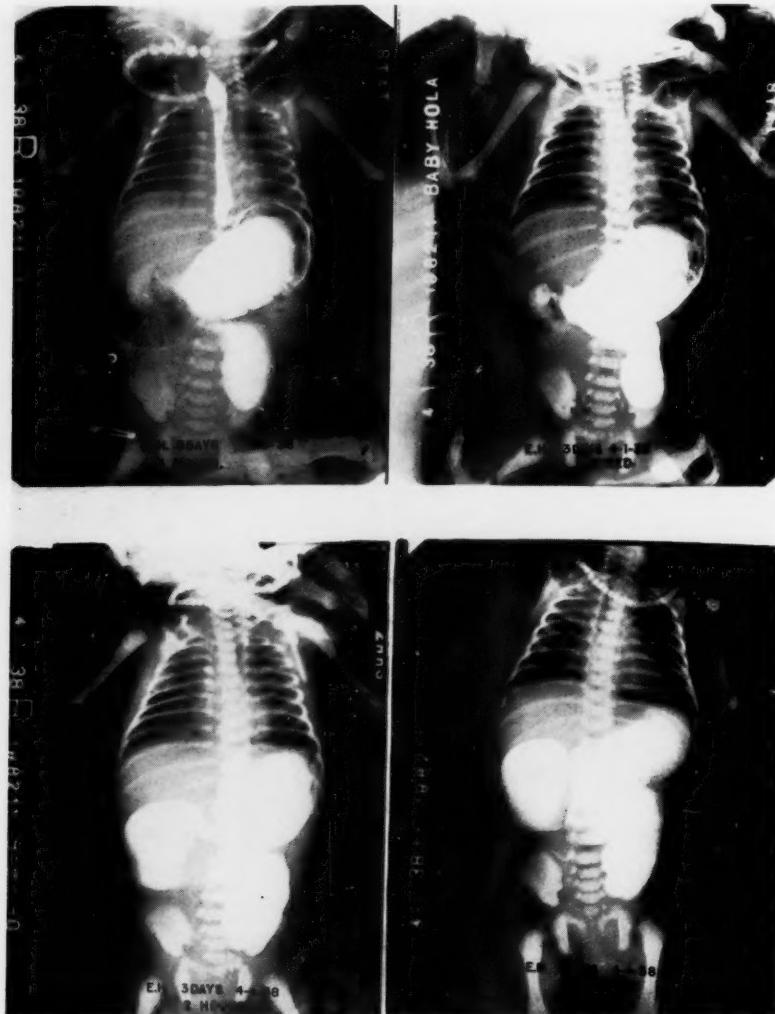


FIG. 1.—Preoperative gastro-intestinal roentgenographic series showing normal esophagus, considerably dilated stomach, with active peristaltic changes; wide open pylorus; tremendously distended duodenum; complete obstruction at duodenojejunal junction; and absolutely no passage of barium beyond point of obstruction after three and one-half hours.

ether-drop anesthesia the abdomen was opened through a median epigastric incision extending below the umbilicus. There was a moderate amount of slightly sanguineous, bile-stained, serous fluid in the abdominal cavity. *Operative Pathology:* A considerably dilated, somewhat thickened stomach was found with a wide open pylorus from which ran a huge, tensely distended, markedly injected, sausage-shaped duodenum of a yellowish-

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pink color, occupying a good part of the abdomen. It was about one and one-quarter inches in diameter and ran from the right upper to the left lower quadrant. It was apparently entirely intraperitoneal, with a distinct mesentery. The wall was definitely thickened. The distended duodenum terminated abruptly, closed by a total, intrinsic diaphragmatic atresia, and continued in a much contracted, thin-walled jejunum which was not much more than one-eighth of an inch in diameter, about the size of the bulb of a mouth thermometer. The balance of the small and large intestine was crowded over to the left side of the abdomen, and the ileocecal junction, with a tiny appendix and a rather

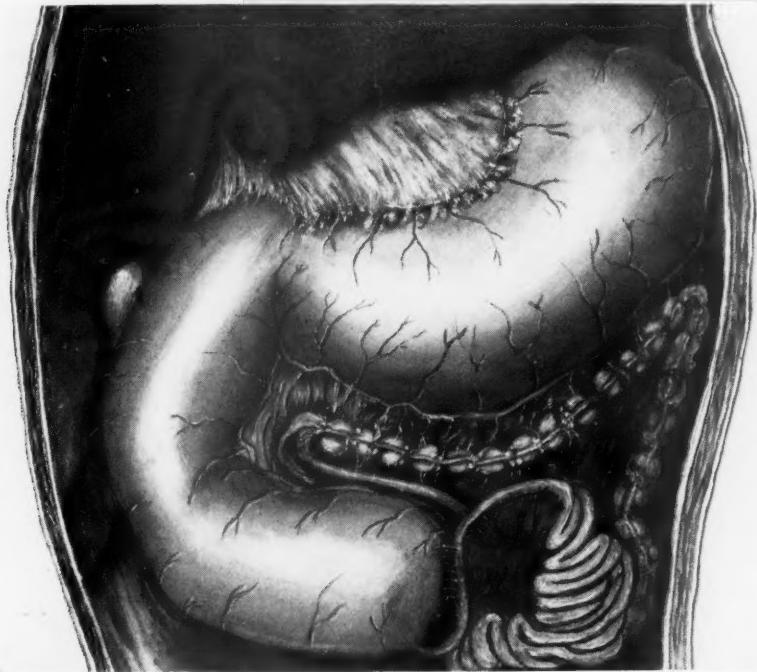


FIG. 2.—Drawing showing findings at operation and operative procedure. Note the dilated stomach with wide open pylorus and huge, distended, intraperitoneal duodenum with total intrinsic diaphragmatic atresia at duodenojejunal junction; much contracted jejunum and ileum; arrested rotation of cecum; and duodenojejunostomy at lowest point of obstructed duodenal loop.

primitive cecum, lay in the angle formed by the stomach joining the duodenum—indicating an arrested rotation of the colon (Fig. 2). The patency of the jejunum below the obstruction was tested and, incidentally, the lumen of the much contracted intestine was widened slightly by the injection of saline solution through a hypodermic syringe, as suggested first by Clogg<sup>9</sup> and, subsequently, by Webb and Wangenstein.<sup>10</sup> On finding the lumen patent, a typical lateral, quite satisfactory antiperistaltic duodenojejunostomy, about five-eighths of an inch in length, was made, employing a double row of very fine, continuous silk sutures at the lowest possible point of the duodenal loop, without the use of clamps. When the duodenum was opened the bile-stained barium and food residue spurted out under marked pressure. There was some difficulty in making the anastomosis and preserving the jejunal lumen because of the extreme disproportion between the size of the duodenum and the jejunum, and also because of the marked difference in the thickness of the walls of the two sections of the intestine. To give a practical illustration of the technical problem involved, the procedure might be compared to the establishment of a lateral anastomosis between a normal adult jejunum and an average-sized median cephalic vein. The abdominal wall was closed in the usual manner in three layers with through-and-through silk sutures through the skin and fascia.

*Postoperative Course.*—The child was put on feedings of breast milk, placed in an incubator, given a small citrate transfusion and repeated clyses. The operation was very well borne by the infant, and there was only a slight rise of temperature to 101.4° F. 12 hours after operation. This, however, immediately dropped to normal and remained there. Three days after the operation, the baby had several small, loose, yellow stools containing barium, bile and milk curds. The jaundice, probably obstructive in character and due to an edema at the papilla, rapidly disappeared but vomiting persisted. That is the usual experience in these cases, as compared with the immediate disappearance of vomiting which regularly follows the successful operation for congenital hypertrophic pyloric stenosis (Fig. 3).

The vomiting continued and was treated by gastric lavage. There was a tendency

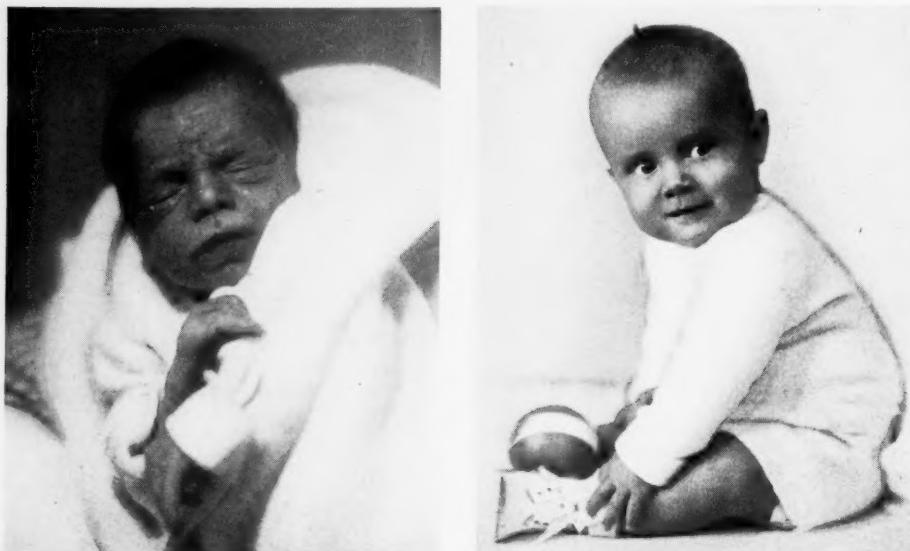


FIG. 3.—Photograph of patient one week after operation.  
FIG. 4.—Photograph of patient at eight and one-half months of age.

toward loose and frequent bowel movements. The child's weight fluctuated between four pounds four ounces and four pounds nine ounces. Another transfusion was given. Two weeks after the operation, Dr. Edward J. Donovan was good enough to see the case in consultation, as I was getting somewhat disheartened because of the persistent vomiting. He advised a continuation of the gastric lavage with an attempt to evacuate the, probably, distended duodenal loop, and felt that the vomiting might be due, mainly, to the partial closure of the stoma because of an edema of the duodenal loop at the site of the anastomosis. A few days later the vomiting stopped and then the baby began to develop a rather intractable diarrhea which at first was thought to be due to a lack of development of the mucosa of the ileum and its lacteals, analogous to the diarrhea from the mucosal atrophy occurring in sprue. The diarrhea was, however, eventually controlled by changing the diet from breast to protein milk.

*Subsequent Course.*—The wound healed *per primam* but a small hernia developed to the right of the scar near the upper angle, apparently due to one of the cutaneous-fascial silk sutures cutting through the fascia. The child was kept in the incubator for five weeks. Two more blood transfusions were administered, and clyses, twice daily, were continued until the diarrhea was controlled, when the baby weighed five pounds four ounces. From then on, the recovery was uneventful, with a gradual increase in weight until the child's discharge from the hospital, June 26, 1938, at the age of three months,

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when its weight was seven pounds two ounces. I feel that the successful result was in a great measure due to the optimistic and devoted care given to the patient by the nurses in charge. Since the child has been under the very excellent and intelligent care of its mother at home, capably directed by Dr. Irwin P. Sobel, it has done remarkably well

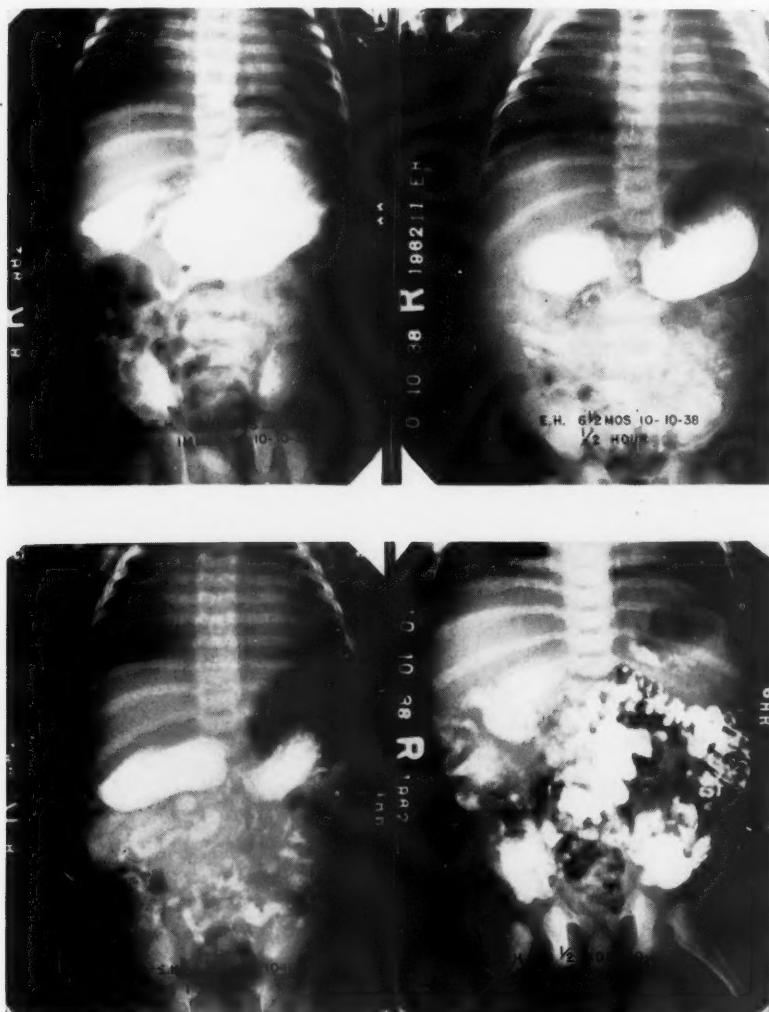


FIG. 5.—Postoperative gastro-intestinal roentgenographic series at age of six and one-half months showing, still, somewhat dilated stomach; satisfactorily functioning anastomosis; and persistent distention of duodenal loop with almost complete emptying of stomach in one hour; and some retention of barium in distended duodenum with a trace in stomach after six hours and with most of barium in colon, head of meal being in distal portion of descending colon. Note the abnormal position of the cecum near the midline, with ascending colon rising therefrom and balance of colon in left side of abdominal cavity.

and has been gaining weight by leaps and bounds. The baby is on the usual mixed diet for a child of its age. It has a hearty appetite, never vomits and seems to have an excellent digestion. Except for a recent, slight, transitory diarrhea, due to some dietary irregularity, the bowels have been regular with perfectly normal stools. The child's mental development, at first, seemed rather slow but gradually it began to progress quite normally (Fig. 4).

A postoperative roentgenologic check-up, October 10, 1938, when the child was six and one-half months old, shows that the stomach, although still somewhat dilated, empties almost completely in one hour, the anastomosis seems to function very well, although the duodenal loop is still quite distended and there is some barium retention in this loop, with a trace still in the stomach at the end of six hours, but most of the barium is in the colon, the head of the meal being in the distal portion of the descending colon. The abnormal position of the cecum is well demonstrated near the midline from which the ascending colon rises, the balance of the colon being in the left side of the abdominal cavity (Fig. 5). The persistence of the dilatation of the duodenal loop, which is known to occur without symptoms in these cases, is apparently causing no disturbance.

*Follow-Up.*—January 13, 1940: The child is now almost one year and nine and one-half months old. He is unusually husky, is in excellent health and has a perfect digestion with normal stools. He has been walking alone and talking since July, 1939, when he was one year and three months old. He is most wide-awake and has cut 16 teeth, the correct number for a child two years of age. His weight is 28 pounds two ounces and his height 33 inches—at least two pounds above the average weight and approximately the average height for his age. The small ventral hernia has almost entirely disappeared.

While the pathologic conditions found in these cases vary greatly, whether the lesions are intrinsic or extrinsic, as classified by Ladd, all have, in common, the almost immediate signs of high obstruction from birth—the persistent vomiting which is bile-stained if the lesion is below the papilla, as is generally the case; no bowel movements or only meconium stools; and rapid loss of weight and dehydration. There is usually a dilated stomach and the diagnosis is generally settled by characteristic roentgenologic findings. The vast majority are either associated with, or directly caused by, a particular developmental anomaly, namely, incomplete or abnormal rotation of the midgut.

As regards treatment, all the cases also have in common the imperative necessity for the earliest possible surgical intervention. As far as the procedure which is indicated is concerned, that will, of course, depend entirely upon the findings. Each case must, naturally, be judged on its own merits, but, in general, it can be said that the operation should be the simplest that can be performed to relieve the obstruction—separation of obstructing bands or reduction of an internal hernia, or if necessary for a true atresia or an irreducible obstruction, an entero-enterostomy. A gastroduodenostomy or a gastrojejunostomy is indicated only, of course, if the obstruction is above the papilla. Resection or ileostomy is contraindicated, as they have an almost 100 per cent mortality.

The extensive diagnostic and surgical experience gained in recent years from the very much simpler problem of congenital hypertrophic pyloric stenosis and the almost 100 per cent success with the standardized method of treatment—the Rammstedt operation—in these cases has, I believe, been largely responsible for the increasing number of correct diagnoses and successful operative results in this other much more complicated and serious condition. We have learned much about the exact, painstaking operative technic necessary in handling the small organs and delicate tissues of the newborn, and the correct methods of anesthesia. We have also learned

that if properly handled the newborn infant has an extraordinary tolerance toward a major operative procedure. This has encouraged us to operate as soon as possible and the perfection of roentgenologic technic has helped us in the early diagnosis. The pediatricians, who have stood by us loyally in all these cases, have taught us much about preoperative preparation and the counteracting of dehydration by clyses and transfusions and also about postoperative supportive treatment, with the continuation of clyses and transfusions, proper nursing and feeding with breast milk or carefully prepared formulae and modern incubation. As a result, we now feel that even very feeble, small, premature infants, if properly prepared, can be successfully operated upon, even within the first few days of their life.

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DISCUSSION: DR. WALTER ESTELL LEE (Philadelphia).—Interest in congenital obstructions of the small intestine has been stimulated in recent years by the pediatricians who have been diagnosing the condition correctly with increasing frequency. The improvement in the surgical management of intestinal obstruction and the advances in the surgery of the gastro-intestinal tract applied to infants have abetted this new interest by affording more hopeful prognoses in these cases. Fortunately the incidence of these cases is not great. Krieg quotes a series of 688,992 consecutive newborn infants collected by E. Theremin, De Sanctis and Craig, Thorndike, and von Kloos, in which there occurred only 31 instances of intrinsic deformities of the duodenum: an incidence of one in 21,580. Without offering any original

contributions to the problem, we feel that it may be worth while reporting two cases which we have encountered because of several unusual features which they demonstrate.

To quote again the frequently repeated statement of J. Bland Sutton: "Congenital obstruction and narrowing of the alimentary canal are always found in the situation of embryologic events." The situations of these embryologic events, in the small bowel, are the regions of the ampulla of Vater and the site of attachment of the omphalomesenteric duct. It is the former region with which we are concerned in the cases to be presented.

In the normal embryologic development the lumen of the small intestine is round and lined with epithelium up to the fifth week of life. By a proliferation of this epithelium the lumen is obliterated soon thereafter. However, by the twelfth week, the lumen is again reestablished by a process of vacuolization of the epithelial cells. Because of the growth of the liver and pancreas from the duodenum this normal process of recanalization of the bowel is sometimes interrupted in varying degrees, and stenosis or atresia or a membranous diaphragm may result.

Forssner's classification of these abnormalities is simple and includes the major possible abnormalities. There may be a diaphragm, complete or incomplete; a stenosis, complete or incomplete; or an atresia with the occluded ends either separated or connected by a fibrous cord. It is impossible to differentiate these conditions preoperatively except to the extent of recognizing that the obstruction is complete or incomplete.

The characteristic symptom of this condition is vomiting which varies in time of onset and severity with the degree of the obstruction. In a case of complete obstruction the vomiting usually begins by the second day and always by the fifth day. The presence of bile in the vomitus is not of special significance because the obstruction may be above or below the ampulla of Vater. In several reported cases there was bile in both the vomitus and the stools due to the opening of an accessory bile duct below the level of the obstruction. There is usually definite evidence of pain or discomfort. Absence of stools is the rule.

The patient is usually distended and shows signs of dehydration and malnutrition after a few days from the onset of the obstruction. Visible peristalsis may be present but is not conclusive. There is frequently a palpable tumor in the right upper quadrant of the abdomen due to the distention of the duodenum. Roentgenologic studies with a barium meal show the stomach normal or dilated, a patent pylorus, and a dilated duodenum proximal to the point of obstruction. In incomplete obstruction small amounts of barium are seen in the small intestine distal to the lesion.

Surgical intervention is necessary to cure cases of intrinsic duodenal obstruction. Since it is usually impossible to detect the site of the lesion by examination of the serosal surface of the bowel, the affected area must be short-circuited by an anastomosis. According to the prevailing opinion the most efficient type of anastomosis is a duodenojejunostomy. This type of operation, employing a single row of fine arterial silk sutures, is the one used so successfully by Ladd. Gastrojejunostomy is frequently more practical, technically, and has been successful in a fair number of cases. Morton was able to localize a congenital diaphragm in one case and excise it with the electric knife. Various details of technic, such as the type of suture material best suited for the anastomosis, and the dilatation of the collapsed bowel distal to the obstruction preliminary to performing the anastomosis, have been emphasized by various authorities on the subject.

One rule that seems to be held unanimously is that a simple jejunostomy is palliative for a short time only and is later followed by death of the patient. In all the cases so treated, except the one reported by Ladd, the patients have died following a simple enterostomy. In view of this fact it is interesting that one of our cases, herewith recorded, recovered and developed normally for a period of eight months following jejunostomy.

## CASE REPORTS

**Case 1.**—Baby U, a white, female infant, was delivered by low forceps from a primiparous mother, March 3, 1936. The delivery was uncomplicated except for slight asphyxia, due to mucus in the posterior pharynx, which was relieved promptly by aspiration. The birth weight was six pounds ten ounces. On the second day after delivery, projectile vomiting began and continued with increasing severity during the third and fourth days. The stools consisted of meconium only.

FIG. 1.

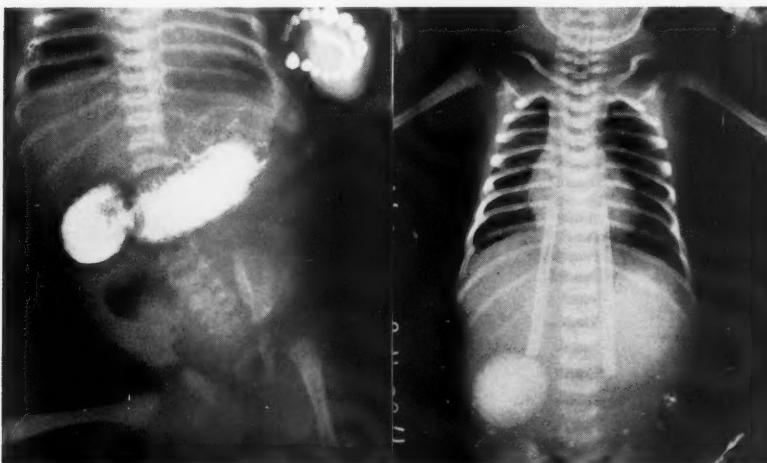


FIG. 2.

FIG. 1.—Four days after birth. Almost complete obstruction to the duodenum.  
FIG. 2.—March 11, 1936: Major portion of barium meal still in stomach and duodenum after 12 hours. A few scattered flakes of barium in the small and large intestines indicate that the obstruction is not complete.

**Physical Examination.**—The abdomen, on the fourth day after birth, showed moderate distention with peristaltic waves passing across it from left to right and occasionally in the reverse direction. The infant was in good condition and not dehydrated, having received adequate amounts of fluids parenterally. A barium meal, administered through a catheter, remained in the stomach and in the dilated proximal duodenum. After one hour no barium had passed beyond the first portion of the duodenum (Fig. 1).

**Operation.**—March 7, 1936: Dr. Walter E. Lee. Numerous adhesions were found extending from the pyloric end of the stomach and duodenum to the gallbladder and liver, which caused constriction of the first portion of the duodenum. These adhesions were separated, and since the child's condition was not good the abdomen was closed without further exploration. Three hours after operation, mouth feedings of Downe's formula were instituted and supplemented by infusions of Hartman's lactated Ringer's solution.

An upper respiratory infection occurred during the next three days which was feared to have developed into a bronchopneumonia. A roentgenogram showed diminished aeration at the apex of the right lung but no evidence of consolidation. A more interesting roentgenologic finding was the presence of the major portion of the barium,

administered four days previously, in the stomach and first portion of the duodenum. A few scattered flecks of barium in the small and large intestine indicated that the obstruction was not complete (Fig. 2).



FIG. 3.—November, 1936: Showing normal physical condition after eight months of jejunal feeding.

FIG. 4.

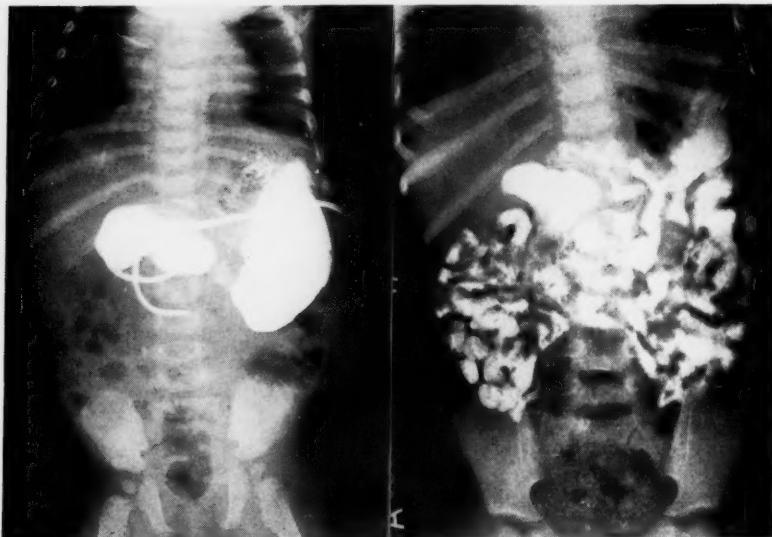


FIG. 4.—Roentgenogram taken eight months after jejunostomy showing almost complete obstruction of duodenum after the injection of a barium meal.

FIG. 5.—June 10, 1938: Roentgenogram taken 19 months after a posterior gastrojejunostomy.

The infant was fortified by a transfusion and by infusions of fluids, and a second celiotomy was performed by Doctor Lee, March 12, 1936. Additional adhesions were found about the duodenum as well as an obstruction of the duodenum in its second por-

## CONGENITAL ATRESIA OF INTESTINE

tion. Because of the patient's critical condition it was thought best to perform as little surgery as possible. Therefore, a simple jejunostomy was performed.

Mouth feedings were carried out for the ensuing 24 hours, but were promptly vomited. On the second day postoperatively, feedings of small amounts of 5 per cent glucose solution in normal saline were administered through the enterostomy tube. Gradually, the mouth feedings were diminished and the tube feedings increased, until two weeks postoperatively, when adequate amounts of breast milk were being given by tube. Later, as the mother's milk diminished, peptonized milk was used as a substitute. Frequent small transfusions were administered during this period and the child gained weight and strength. The operative wound healed completely except for the jejunostomy opening which admitted a No. 8 Fr. catheter.

During the fifth and sixth months postoperatively, the infant's weight remained stationary at 12 pounds. At the end of the seventh month the weight had increased to 14 pounds (Fig. 3). Roentgenologic examination, however, showed practically a complete obstruction of the duodenum to be still present (Fig. 4).

FIG. 6.

FIG. 7.

FIG. 8.

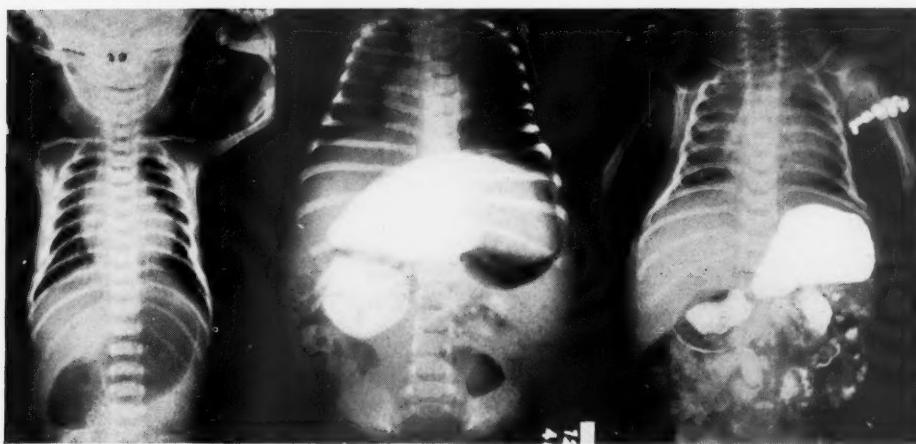


FIG. 6.—May 1, 1938: Roentgenogram taken three days after birth shows an abnormal distention of the stomach and duodenum with air.

FIG. 7.—May 2, 1938: Roentgenogram taken four days after birth shows almost complete obstruction to the passage of a barium meal in the second portion of the duodenum.

FIG. 8.—June 14, 1939: Roentgenogram taken 33 days after an anterior gastrojejunostomy.

November 10, 1936: Eight months after the original operations, a third celiotomy and posterior gastro-enterostomy, using silk sutures, were performed by Doctor Lee. Following the operation, tube feedings were carried on as usual for one week and then gradually diminished while mouth feedings were instituted. At the end of the second week postoperatively all nourishment was administered by mouth.

*Subsequent Course.*—The child showed a progressive increase in weight and has not vomited since the last operation. The jejunostomy persisted for six weeks but was finally closed by constant plugging of its orifice and by approximating the skin edges. Roentgenologic studies, June 10, 1938, showed that the gastro-enterostomy was functioning perfectly (Fig. 5).

At the present time, January, 1939, the child is normal in both weight and development.

**Case 2.**—Baby H, a white, male child, was delivered spontaneously, May 1, 1938, from a healthy mother, who had one older child living and well. The birth weight was six pounds one ounce. There were no external abnormalities. Soon after birth the child began to have attacks of cyanosis followed and relieved by the eructation of mucus. On

the second day after birth, these eructations became more frequent, and after taking water by mouth there was bright red blood in the vomitus. The infant grew quite listless, and had an almost continuous stream of fluid coming from both nose and mouth. Nothing taken by mouth was retained.

On the third day after birth, a roentgenogram of the chest showed evidence of incomplete expansion or possibly bronchopneumonia in both lungs. Fluoroscopic and film examinations with barium in the esophagus showed no abnormality in swallowing.

Mouth feedings were stopped on the third day and glucose and normal saline solutions were administered hypodermically. Regurgitation of everything taken by mouth, in the form of a brownish liquid, continued on the fourth day. There had been no stools. Roentgenologic examination of the abdomen revealed the following information: There were two large pockets of air in the epigastrium divided by a narrow line, the left pocket being larger than the right (Fig. 6). A portion of the barium given 24 hours previously had been regurgitated but most of it was trapped in the two air pockets, flowing freely between them. A small portion of the barium had reached the small intestine (Fig. 7). The conclusion was that a high obstruction existed, probably in the duodenum.

*Operation.*—May 5, 1938: An exploratory celiotomy was performed by Doctor Lee. The stomach, and first and second portions of the duodenum were markedly distended. The pylorus was dilated but not hypertrophied. The obstruction was probably in the retroperitoneal portion of the duodenum. An anterior gastrojejunostomy was performed and the abdomen closed.

During the first three days postoperatively, the infant had a temperature ranging from 100° to 102° F. This, however, subsided on the sixth day. Transfusions and parenteral fluids only were administered until the second day, when small amounts of water were given by mouth. On the third day diluted breast milk was given successfully.

The first small meconium stool was passed on the second day postoperatively, while on the fifth day the stools contained bile and milk curds.

The child showed a slow but continuous gain in weight from May 9, the fourth day postoperatively, until June 25, when he weighed seven pounds 11 ounces on discharge from the hospital. Regurgitation of small amounts of bile-stained fluid after each feeding began about one week after operation and continued throughout his hospital stay. This phenomenon is still going on, although intermittently, and the amounts of fluid regurgitated are small.

*Follow-Up.*—June 14, 1938: A roentgenologic study showed the gastro-enterostomy functioning well. More than one-half the barium meal had left the stomach at the end of one and three-quarters hours. The first portion of the duodenum remained dilated, and no barium was seen leaving the duodenum in the normal manner (Fig. 8).

*Discussion.*—It is interesting that in the second case the primary difficulty was thought to be in the chest and, indeed, the roentgenograms of the chest were helpful in directing attention to the real source of trouble. A correct diagnosis of obstruction of the duodenum was then made. This same sequence of events occurred in an infant recently treated at the Children's Hospital of Philadelphia. It leads one to speculate about the possible origin of the pulmonary condition from compression due to the distended stomach and duodenum.

The incompleteness of the obstructions was demonstrated by the presence, in both patients, of small amounts of barium distal to the sites of obstruction. Therefore, we realized that the pathology was not that of atresias, but either incomplete diaphragms or stenoses which caused partial blocking of the lumina. Both cases illustrate the usual difficulty experienced in determining the nature of the lesion as well as its exact location by examination of the external surface of the bowel.

The first infant is remarkable in that she survived a period of eight

## CONGENITAL ATRESIA OF INTESTINE

months' feeding via an enterostomy tube. This jejunostomy was performed despite the knowledge that such a procedure had been proven to be poorly tolerated in other similar cases, because we believed the critical condition of the patient would not permit of a more lengthy operative procedure. The fact that the child lived is a tribute to the nurses and residents who attended it and to the carefully planned postoperative regimen of feeding outlined by Doctor Stokes.

The second patient was in better general condition at the time of operation. Our choice of procedure lay between duodenojejunostomy and gastrojejunostomy. The former procedure was not carried out because the extreme distention of the proximal duodenum had distorted the anatomy to a marked degree. It was feared that after decompression an angulation might occur at the site chosen for the anastomosis and thus give rise to a secondary obstruction.

TABLE I

Age at Operation	Recovered*	Died
30 hrs.		yes
2 days		yes
4 days		yes
5 days	yes	
6 days	yes	
7 days	yes	
8 days	yes	
12 days	yes	
14 days	yes	
16 days		yes
23 days	yes	
29 days	yes	
3 mos.		yes
4½ mos.	yes	
5 yrs.	yes	
8 yrs.	yes	
9 yrs.	yes	
12 yrs.	yes	
Totals	13	5

\* Two newborn babies with obstruction, probably from volvulus, recovered without operation.

In this case, eight months postoperatively, there is a persistent regurgitation of bile after feedings. The exact mechanism of this phenomenon has not been explained. It is possible that the continuance of the mechanism for the secretion of bile, after food has left the stomach rapidly via the jejunostomy, may bathe the gastric mucosa with undiluted bile for long periods. This condition may then give rise to irritation which in turn initiates and is relieved by regurgitation.

DR. EDWARD J. DONOVAN (New York) said that at the Babies Hospital there have been 38 similar cases. For simplicity these may be divided into intrinsic and extrinsic lesions. The intrinsic lesions are usually a membranous diaphragm, a complete atresia, and stenosis, which represents a lesser

degree of closure of the lumen. The extrinsic lesions are caused by (1) volvulus of the small intestine due to a failure of fixation of the ascending colon to the parietal peritoneum in the right lower quadrant of the abdomen; (2) developmental bands; and (3) fixation of the duodenum in an abnormal position. Both types of lesion are often associated with some error of rotation of the embryonic midgut loop. In the January issue of the American Journal of Diseases of Children, Doctors McIntosh and Donovan reported 20 cases, from the Babies Hospital, of malrotation of the intestine with duodenal obstruction. Of the intrinsic lesions of the duodenum there have been 18 cases, eight of whom died before operation could be performed. Ten of the 18 cases were operated upon and five died. All but two\* of the 20 cases with extrinsic lesions were operated upon and five of them died. The 20 cases with extrinsic duodenal lesions, therefore, did very much better. Table I shows the age at operation and the results of obstructions due to extrinsic lesions.

If the obstruction of the duodenum is complete, these patients suffer all the ills of high intestinal obstruction, and are often in bad condition when they are brought to the hospital. As soon as their fluid balance can be restored they are operated upon, and it often means subjecting a small baby to a very severe operative procedure which he cannot stand. The intrinsic lesions more often cause acute obstruction very early in life and for this reason the mortality is considerably higher.

The technical difficulties encountered in operating upon some of these cases, particularly where anastomoses have to be undertaken, and there is a great difference in the size of the two loops of intestine to be anastomosed, can be appreciated from Doctor Stetten's case report.

## SURGICAL CONSIDERATION OF HYDATID DISEASE

REPORT OF SOME UNUSUAL CASES

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THE HIGH INCIDENCE of hydatid disease in Syria has been reported by Turner, Dennis and Kassis.<sup>1</sup> In the Hospital of the American University of Beirut, the records of the surgical service show that during the last ten years (1928-1938) one out of every 150 patients had hydatid disease. Syria is a pastoral country. The interrelation between sheep and dogs, and the unhygienic way in which sheep are slaughtered, favor the maintenance of the life cycle of the *echinococcus granulosus*, and while the water supply is being constantly improved there is still a great deal of pollution.

The distribution of the disease in the different parts of the body is similar, in Syria, to that in other countries. Our statistics show that it occurs in the liver in 50 per cent of the cases, in the lungs in 20 per cent, and in the other organs in 30 per cent.

The diagnosis is fairly easy in the majority of cases but may be difficult or impossible in others. A hydatid cyst may lie dormant in the body and give rise to no symptoms whatever, and it may be occasionally found during the search for other abdominal conditions or at autopsy. When the cyst grows in palpable organs such as the liver, spleen or kidney, it may be felt as a rounded, uniform, smooth and almost painless mass attached to the viscus or embedded in its substance, and is, as a rule, freely movable with the organ with which it is associated. If the cyst is rich in daughter cysts and near the body surface, it may give a fremitus (hydatid thrill) which may either be felt with the hand or, better, heard with the stethoscope. In cysts that are not accessible to palpation, such as pulmonary cysts, roentgenograms are an invaluable aid in diagnosis. They cast a well defined, rounded shadow which is uniform in density.

Hydatid disease was the first of the pathologic conditions caused by animal parasites in which serologic tests proved to be of great value in diagnosis. The complement fixation test of Weinberg, and the skin sensitivity test of Casoni, are very helpful in making a positive preoperative diagnosis. In our experience, the Casoni reaction was positive in 90 per cent of the cases demonstrated by operation to be hydatid disease. Occasionally a positive Casoni reaction will be obtained in a patient in whom hydatid infestation could not be found during operation. In these cases, there may be a small cyst which has not been found or the allergy may be the result of an infestation which was successfully taken care of by the tissue defenses of the body. The Casoni test is the method

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of choice for testing a tentative diagnosis, but if it fails, a complement fixation should be done.

The relation of hydatid disease to the body economy is significant, as, aside from infection and its untoward effects, the pressure of the cyst may prove incapacitating, harmful, dangerous and even fatal. One-fourth of our cases were infected before they came for operation, the colon bacillus being the most frequent invader. The mode of infection of the cyst with micro-organisms is not definite and the various theories advanced are not clear. The most plausible explanation is the occurrence of pericystitis extending from the capillaries of the adventitious capsule, where, owing to their tortuosity and the resulting stagnation of blood, a clot may be formed and become invaded by micro-organisms circulating in the blood stream. A suppurating hydatid cyst may be difficult to differentiate from an ordinary abscess.

The local effects of the cyst are manifest by a sense of discomfort and sometimes a disturbance of the function of the organ invaded. In hepatic cases, there may be severe jaundice from pressure on the bile ducts. They may rupture into the biliary ducts or into the intestines and discharge their contents into the bowel. Pulmonary cysts may produce a sense of oppression in the chest and very often cough and expectoration of blood-stained mucus, which is a misleading symptom often leading to a diagnosis of pulmonary carcinoma or tuberculosis. Cysts of the orbital cavity may interfere with vision. In the brain they may produce serious and distressing symptoms.

Rupture of a hydatid cyst into the peritoneal or pleural cavities may be very serious. Signs of severe anaphylactic shock appear very quickly. In the chronic cases the reaction seems to be milder. In two of our cases, there was a rupture of the cyst—one in the liver and the other in the spleen—into the abdominal cavity. Symptoms of mild anaphylactic shock appeared which were quickly relieved by adrenalin. One of these cases was seen two years later and evidenced no signs of any recurrence or abdominal involvement.

The surgical treatment of hydatid disease depends upon the location of the cyst and its situation in the organ. The old practice of tapping the cyst is to be condemned as both unreliable and dangerous. The ideal treatment is to excise the cyst with its adventitious capsule, but this is possible in only a few cases where the cyst is attached to the surface of the organ with a sort of pedicle and can be extirpated without damage to the organ.

**Case 1.**—K. A., male, age 35, laborer, was admitted to the hospital, March 15, 1928. *Chief Complaint:* An increasing bulging of the left eye of 15 months' duration. The left eyeball protruded almost out of the orbit. With the exception of a mild optic atrophy, the vision and the ocular tissues were unimpaired. A roentgenogram showed no bone lesion. Blood count: 7,500 leukocytes, with 3 per cent eosinophils. Wassermann negative. A tentative diagnosis of nonmalignant tumor of the orbit was made.

*Operation* was performed under general ether anesthesia. A cyst the size of a small walnut was found between the eyeball and the orbit externally, surrounded by very loose adhesions. The cyst and its membranes were removed completely and the patient made an uneventful recovery. The cyst contained 15 cc. of straw-colored fluid and hooklets were seen under the microscope. When seen a year later vision had been completely recovered.

**Case 2.**—G. S., male, age 25, clerk, was admitted to the hospital, January 4, 1928. *Chief Complaint:* Pain and heaviness in the right hypochondrium of four years' duration, associated with anemia and easy fatigability. *Examination* showed a mass the size of a small grapefruit hanging from the lower border of the liver. The mass was round, smooth and movable. Hydatid thrill was elicited over the mass. Casoni positive. Blood showed 8,500 leukocytes, with 4 per cent eosinophils. A diagnosis of hydatid of the liver was made.

*Operation* was performed under general ether anesthesia. On opening the abdomen the cyst was found loosely attached to the under surface of the liver. It was very easy to enucleate and was entirely removed. Recovery was uneventful and the patient was discharged, February 8, 1928 (Fig. 1).



FIG. 1.—Case 2: Hydatid of the liver.

In the majority of hepatic cysts, however, the cyst is found embedded in the substance of the liver but tends to bulge through to the periphery. In these cases, the first concern of the surgeon is to determine the method of approach. If the cyst is near the anterior border of the liver, on its under surface or in the left lobe, the best approach is through the abdomen. The abdomen is opened by a vertical incision over the most prominent part of the cyst, and the capsule of the cyst is sutured by a continuous suture to the parietal peritoneum leaving an exposed area 4 cm. in diameter. In four to six days the two layers of the peritoneum become adherent, closing off the general peritoneal cavity (marsupialization) and the second stage of the operation could be undertaken.

In the choice of the handling of the cyst we have been guided by the special indications present in each case. We tap the cyst, inject 2 per cent formalin and after a few minutes open the cyst with the electric cautery. The contents are then evacuated and with a sponge forceps the daughter cysts and cyst membranes are removed. If the cyst cavity is large, we drain it. If small, we fill it with normal saline solution and close it tight. In a few cases, we have omitted the use of formalin without subsequent recurrence. Cysts located in

the dome of the liver are treated like pulmonary cysts. Occasionally a cyst might be so large as to require a counteropening either through the abdomen or through the chest. If the two layers of the peritoneum or pleura are already adherent, the cyst is opened immediately.

All pulmonary cysts are handled in the following way: The cyst is carefully located by means of stereoscopic roentgenograms. The operation is performed in two stages. During the first stage, two or three ribs are resected over the area where the cyst is nearest the chest wall. In some cases the adventitious capsule of the cyst is seen moving with respiration within the pleura. In this case a circular suture is made fixing the capsule to the parietal pleura. When this is not possible a piece of gauze soaked in tincture of iodine is placed on the parietal pleura and gently pressed in. In ten to 14 days adhesions will have formed firm enough to allow the performance of the second stage. The cyst is then aspirated, opened with the electric cautery and its contents evacuated. In most cases we have been able to remove the cyst membranes in their entirety with a sponge forceps. In a few cases the membranes were very friable and it was impossible to remove them completely. The little that is left comes out on the dressings. None of the lung cysts were formalized, and we have had no recurrences. This method has given us satisfactory results though in some cases the recovery was slow. Multiple cysts of the lungs are not infrequent. In the treatment of such cases the cysts must be handled one at a time.

**Case 3.**—F. D., female, age 25, housemaid, was admitted to the hospital, November 16, 1934. *Chief Complaint:* Dull pain and heaviness in the left chest in the region of the scapula of eight months' duration. On May 2, 1934, the patient was seen at the Out-Patient Department, when a yellowish fluid was aspirated from the left pleural cavity (?) and a diagnosis of pulmonary tuberculosis made. *Examination:* On admission there was dulness over the right apex and the left base. Leukocytes 7,750, with 6 per cent eosinophils. Casoni positive. *Roentgenograms* showed three opaque, rounded, intrapulmonary shadows clearly outlined. The first was the size of an orange, below the right clavicle; the second the size of a small grapefruit, above the left diaphragm, and the third a small one seen behind the second.

On November 29, 1934, the cyst on the left side was operated upon. Under local infiltration anesthesia, 5 cm. of the eighth and ninth ribs were resected along the posterior axillary line. The two layers of the pleura were seen to be adherent to each other (possibly as the result of the previous paracentesis). The cyst was tapped and the fluid contained hooklets and scolices. It was then opened with the electric cautery and the contents of the cyst as well as the cyst membranes were removed with a sponge forceps. A Pezzer catheter was inserted and the cavity drained. On January 3, 1935, the right cyst was operated upon under local anesthesia. Five centimeters of the fifth and sixth ribs were removed along the posterior axillary line. The pleura was sutured to the capsule of the cyst in a circular manner and the wound packed with sterile gauze. On January 15, the wound was exposed, the cyst tapped and the fluid found to contain hooklets and scolices. It was opened with the electric cautery, the membranes removed with a sponge forceps and a Pezzer catheter introduced into the cavity. On February 15, 1935, the roentgenologist reported: "There are operative defects of the fifth and sixth ribs posteriorly on the right and the eighth rib laterally on the left. The rounded shadows in the left base have disappeared. The cyst of the right lobe is replaced by an annular haziness

## HYDATID DISEASE

surrounding an empty area (Figs. 2 and 3)." On February 19, the patient was discharged completely recovered. Evidently the third small cyst must have emptied through the second.

Cysts of the spleen are not so rare, and are generally easy to diagnose. They may be treated as those of the liver, but if they are of large size, a splenectomy is the method of choice, especially as no adhesions are usually encountered.

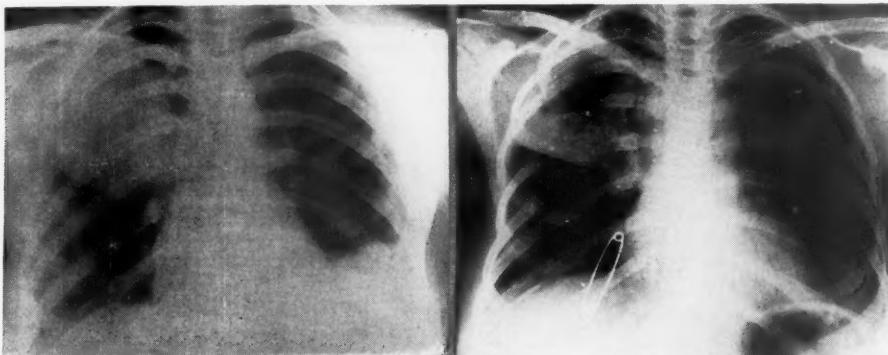


FIG. 2.—Case 3: Hydatid of the lung. (Before operation.)

FIG. 3.—Case 3: Hydatid of the lung. (After operation.)

**Case 4.**—L. K., female, age 33, housewife, was admitted to the hospital, October 25, 1927. *Chief Complaint:* A painless swelling in the left hypochondrium of two years' duration. *Examination* showed a mass the size of a large grapefruit, firm in consistency, rounded, painless, attached to the lower border of the spleen and freely movable. Casoni positive. Leukocytes 8,300, with 5 per cent eosinophils. The diagnosis of a hydatid of

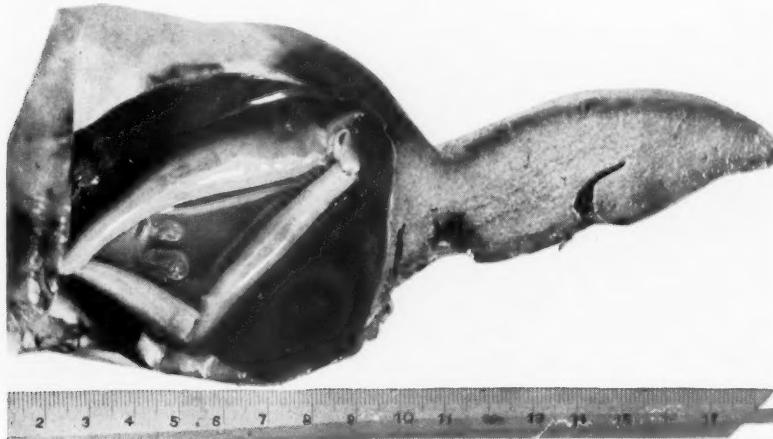


FIG. 4.—Case 4: Hydatid of the spleen.

the spleen was made. Splenectomy was performed under general ether anesthesia, October 28. There were no adhesions, and the spleen and the cyst were freely movable. Recovery was uneventful and the patient was discharged, November 14. The cyst contained daughter cysts and hooklets (Fig. 4). The patient was seen three years later and was in good physical condition.

Cysts of the kidney are more difficult to diagnose. Partial nephrectomy is the method of choice. If the cyst is large and the kidney tissue is damaged, complete nephrectomy is advisable providing the other kidney is in good condition.

**Case 5.**—M. Y., female, single, housewife, age 24, was admitted to the hospital, December 3, 1934. *Chief Complaint:* A mass in the right upper quadrant of three years' duration. Retrograde pyelography showed an enlarged kidney with probable hydro-nephrosis. Leukocytes 6,750, with 3 per cent eosinophils. Blood urea nitrogen 7.5 mg. Renal function (P.S.P.) 56 per cent—right kidney 16 per cent and left kidney 40 per cent. A diagnosis of tumor of the right kidney was made. On December 15, the patient was operated upon under general ether anesthesia. A cystic mass the size of a grapefruit was found protruding from the lower pole of the kidney. Clear fluid was aspirated, and immediate microscopic examination revealed the presence of hooklets and scolices. Nephrec-

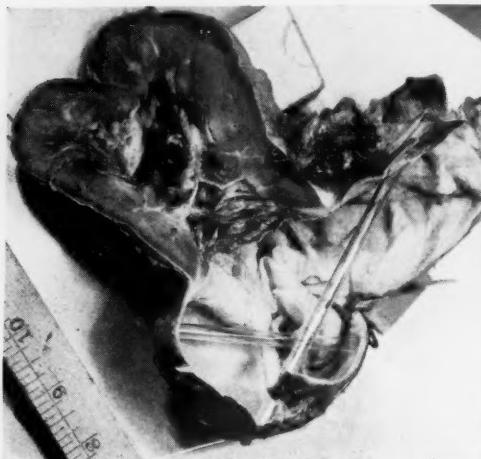


FIG. 5.—Case 5: Hydatid of the kidney.

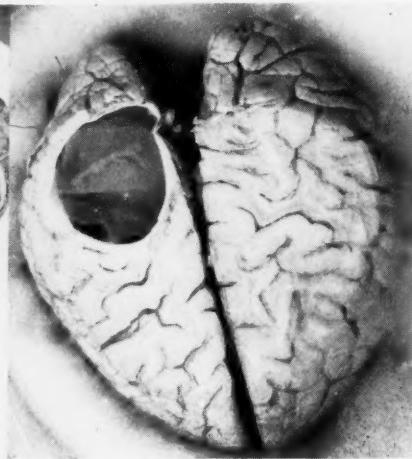


FIG. 6.—Case 7: Hydatid of the brain.

tomy was performed. Recovery was uneventful and the patient was discharged, December 26 (Fig. 5).

Hydatid disease of the pancreas is rare. Masseron<sup>2</sup> has been able to collect the record of five cases only, and these were first recognized at autopsy. Graham,<sup>3</sup> of Sidney, says: "The hydatid is sometimes found in the pancreas. I have observed it as cyst about three inches in diameter replacing the head of the pancreas." Tricomi<sup>4</sup> states, without giving any references, that seven cases have been recorded. One of the most interesting of our cases was a large hydatid of the tail of the pancreas.

**Case 6.**—F. M., female, age 40, housewife, was admitted to the hospital, September 19, 1926. *Chief Complaint:* Pain and heaviness in the epigastrium with a feeling of fulness in the stomach after meals, of three years' duration. *Examination* revealed the presence of a deep-seated mass under the xiphoid cartilage, very slightly movable, rounded in contour and of firm consistency. It was the size of a grapefruit and situated behind the stomach. Under the fluoroscope the barium meal was seen to spread out in the stomach, taking the shape of a ring, caused by the pressure of the mass behind. Stool examination and stomach contents were negative. Wassermann negative. Leukocytes 7,500. No

## HYDATID DISEASE

Casoni or Weinberg was done as hydatid disease was not suspected. *Diagnosis:* Tumor of the pancreas.

*Operation.*—September 25, 1926: Under general ether anesthesia, a median, vertical subxiphoid incision reaching to the umbilicus was made. On opening the abdomen, a mass the size of a grapefruit was found lying behind the stomach and lesser omentum. The nature of the mass could not immediately be ascertained. On opening the lesser sac a fluctuating cyst was seen arising from the tail of the pancreas. The enlarged splenic artery was adherent to the capsule of the cyst. The octahedral pavement effect produced by the daughter cysts revealed the nature of the condition. The abdominal cavity was well protected with wet pads and the cyst aspirated. Immediate microscopic examination showed the hooklets and scolices. The fluid was aspirated, the cyst opened with the elec-



FIG. 7.—Case 8: Hydatid of the medulla.

tric cautery and the contents evacuated. The capsule was resected except the small portion that was attached to the splenic artery. This small remaining portion was cauterized with carbolic acid and alcohol and doubly inverted by a continuous suture of chromic gut. The lesser omentum was sutured and the abdomen closed. The patient made an uneventful recovery and was discharged, September 30, 1926. This patient was seen in August, 1937. She was in good health with no signs of recurrence.

Primary hydatid cyst of the brain is rare and the condition is generally incompatible with long life. In our series we had two cases of brain cysts, both of which were recognized at the autopsy.

**Case 7.**—B. S., female, age 25, was admitted to the hospital, February 25, 1932. *Chief Complaint:* Impairment of vision since December, 1930, leading to complete loss of

vision in the right eye eight months later. Attacks of frontal headache with occasional vomiting. Ophthalmoscopic examination showed right optic atrophy. Leukocytes 4,750, with 2 per cent eosinophils. Wassermann of cerebrospinal fluid and of blood negative. Patient died, March 6, 1932. Autopsy showed a hydatid cyst of the right occipital lobe (Fig. 6).

**Case 8.**—A. K., male, age 27, was admitted to the hospital, November 15, 1922. *Chief Complaint:* Pain in the head and vomiting. Bilateral papillitis. Wassermann positive. *Diagnosis:* Tumor of the brain, probably syphilitic. Patient died, December 9, 1922. Autopsy showed a hydatid cyst of the medulla encroaching upon the quadrate lobe of the cerebellum (Fig. 7).

While hydatid cysts are often found in the liver and the lungs, they may be found anywhere in the body. We had three rather unusual cases as far as the site is concerned. One was a hydatid of the muscles of the back and the other two were in the buttocks.

**Case 9.**—H. M., male, age 59, peddler, was admitted to the hospital, April 12, 1933. *Chief Complaint:* A painless swelling in the right loin of two years' duration. *Examination:* A uniform, fluctuating mass the size of a grapefruit was found situated over the crest of the ilium. No limitation of motion of the vertebral column. Roentgenograms of the spine negative. No temperature. Leukocytes 6,300, with 8 per cent eosinophils. Casoni and Weinberg positive. *Diagnosis:* Hydatid cyst (possibility of a cold abscess).

*Operation.*—Under local infiltration anesthesia, April 15, 1933, a cyst was found arising from the muscles of the back. The aspirated fluid showed hooklets and scolices. The cyst was opened and evacuated and the membranes removed. The cavity was swabbed with tincture of iodine and closed without drainage. Recovery was uneventful and the patient was discharged, April 23. He was seen two years later and showed no evidence of recurrence.

The treatment of infected hydatid cyst is that of an ordinary abscess, namely, free incision at the most suitable site and the establishment of free drainage.

General ether anesthesia has been our anesthetic of choice, as it minimizes the occurrence of anaphylactic shock. In lung cases we have employed local infiltration anesthesia with  $\frac{1}{2}$  per cent novocain with adrenalin, in order to prevent congestion of the lungs and coughing which might rupture the cyst and disseminate its contents into the bronchi and lungs.

#### SUMMARY

- (1) Hydatid disease is not rare in Syria. It forms 0.6 per cent of our surgical cases.
- (2) With our present diagnostic aids, diagnosis, in the majority of cases, is not difficult.
- (3) Cysts are usually located in the liver or lungs but may be found anywhere in the body.
- (4) A few rather unusual cases are detailed and their treatment described.

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## LYMPHANGIOMATA OF THE GREAT OMENTUM

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LYMPHANGIOMATA, seen with some degree of frequency in other portions of the body, occur much less often in the abdomen and particularly in children. According to Ewing,<sup>1</sup> the solid tumors of the mesentery and omentum springing from the tissue within the peritoneal leaves are usually of connective tissue origin, as lipoma, fibroma, and sarcoma. These growths also present in the retroperitoneal space. Lipoma is the most frequent of the mesoblastic tumors in the peritoneal structures, but all are rare. Cystic growths of a more complex type are found in this region and are much more common here than the solid tumors. This appears to be particularly true also of the lymphangioma, and they are almost all cystic in type. The solid or noncystic lymph vascular tumors are perhaps the rarest of all. Naturally, from the formation of the lymphatic vessels and particularly those in this region, cyst formation would be expected to occur. They sometimes reach large size because of the vascularity of the region and the looseness of the structures. It is noteworthy that tumors of loose cellular structure grow more steadily under these conditions, even though essentially benign in character. These cysts are thin-walled and have a limited blood supply. They are usually filled with a pale serum but sometimes contain a dark or even bloody fluid. In a few cases such growths, closely adherent to the intestinal tract or in intimate relation to the lymph ducts, may contain a milky fluid—chyle cysts. Rarely the neoplasm, as in our case, is made up for the most part of firm lymphatic and connective tissue with little or no fluid content. They usually cause symptoms by pressure upon surrounding structures creating distress and discomfort rather than actual pain. The exceptional cases cause pain because of the involvement of some portion of the gastro-intestinal tract, with obstruction of its lumen or constriction of its vascular supply. These growths are essentially benign and usually do not recur after removal.

From the frequent blocking of the lymph channels in the great omentum, due to pelvic and other inflammatory disease within the abdomen and with considerable trauma to the omentum, tumors would be likely to result more frequently if they were caused by such occurrences. Apparently this result does not follow, and one is justified in concluding that most omental growths are congenital in origin, as has been suggested by Nasse,<sup>2</sup> Ribbert,<sup>3</sup> Sisk<sup>4</sup> and others, notwithstanding Wegner's original experiments on the injection of air and filling the abdominal cavity under pressure and choking the lymph channels, resulting in the production of large cysts with proliferative changes in the

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walls. Undoubtedly blocking of the channels either from inflammatory or neoplastic change increases the growth of the tumor. Omental growths usually show serous or blood-tinged (sometimes quite dark) fluid within the cysts and differ materially from the milky fluid found in chylous cysts resulting from obstructions of the lymph ducts draining the lacteals. In rare instances omental lymphangioma may show but very small cysts and their structure consist largely of true lymphangiomatous tissue with considerable, rather loose, connective stroma.

Sabin,<sup>5</sup> Huntington and McClure (mentioned by Singleton<sup>6</sup>) have thrown new light on the development of the lymphatics. Huntington and McClure<sup>7</sup> seem to have established the fact that the development of the lymph vessels begins at definite centers and from such a center vessels spread outward, vascularize and drain a definite area. Excisions of the starting center result in no growth and vessels from neighboring areas invade and drain the one thus deprived. These findings seem to agree with the well-known tendency of lymphatic structures, both glandular and vascular, to increase in size, number, and activity and to overcome irritants, traumatic, chemical, bacterial or toxic. These vessels and glands also have the power to return to their normal size and distribution when the causative agent is destroyed or removed. The entire process of nutrition is so closely dependent upon lymphatic absorption and distribution of fluids that wonder is not excited by the great activity of these structures in defense of the organism against disease and in repair of damage of all kinds.

The study of 53 cases of lymphangioma of the omentum by A. H. Montgomery and I. J. Wolman,<sup>8</sup> in 1935, is most comprehensive; 35 of these cases were under 11 and 18 over 11 years of age. It appears, therefore, to be an affection of childhood, and this fact taken in connection with other circumstances points to its congenital origin. In the 53 cases recorded, only in one case was the correct preoperative diagnosis recorded. In part this is due to the slow onset and the vague history but it also is the result of the rare occurrence of the affection as well as the difference in the physical findings.

*The important point is to keep in mind the fact that such a neoplasm does occur in childhood.* Some cases begin as a small, mobile, painless growth in the abdomen of an infant. The condition is more likely to present in the epigastrium, the umbilical or right lower quadrant. It will usually be smooth and irregularly round until it becomes attached to the abdominal wall, the intestine or some other structure from inflammatory adhesion. Fluctuation is likely to be elicited early in its development. Pain is not important early in most cases. The first symptoms, however, may be the result of a torsion of the omentum or intestinal stasis from obstruction of the lumen or from blocking of the intestinal blood supply. Under such conditions the case becomes a grave surgical emergency.

Even in the early stages in younger children malnutrition is evident, with constipation from the effect of pressure, while occasionally a troublesome dia-

## LYMPHANGIOMATA OF OMENTUM

rhea persists. Nausea and vomiting are often present at the onset. Such occurrence is so frequent in infants that its cause may be searched for in some more usual lesion and a neoplasm overlooked. The fact that it does occur in infancy should be kept in mind by the observer. In the early stages of its development any of the acute ills of an infant are to be differentiated. In the later stages its recognition is based upon its slow development, its increasing size, the contour of the abdomen without any evident increase in general nutrition. An afebrile condition also points in its direction although fever, leukocytosis and general distress with abdominal rigidity may simulate appendicitis.

Tuberculous peritonitis is most likely to be mistaken for lymphangioma, but tuberculous lesions are more likely to be irregular in contour. Both conditions are likely to be accompanied by ascites and then a fluid wave is elicited, together with a flat percussion note. Sarcoma grows with more rapidity and affects the health of the patient more promptly. It is also more rapidly fatal.<sup>9</sup>

In older patients, ovarian cysts, renal and splenic growths, torsion of the omentum or of an ovarian cyst may confuse the clinician. Prolonged observation can only confuse, and if the use of radiologic investigation with intra-peritoneal air added, if necessary, does not clarify the diagnosis, an open abdomen will disclose the trouble and perhaps afford relief.

The report herewith submitted adds another lymphangioma of the omentum to the 53 cases previously reported in surgical literature. In this instance a diagnosis of intra-abdominal tumor with pressure symptoms was charted before operation.

**Case Report.**—P. P., female, age three, was admitted to the hospital, January 20, 1937. About three months previously the mother noted an enlargement of the child's abdomen which has been progressive during the past week, dyspnea has been extreme, accompanied by pain in the abdomen. Intermittent vomiting has occurred. The past history is essentially negative, with the absence of childhood diseases.

**Physical Examination.**—One was immediately impressed with the extreme condition of the child, which presented an anxious face with flushed cheeks, some cyanosis, and marked dyspnea.

The abdomen is very much distended, enlarged and rounded in contour due to an intra-abdominal mass. The skin has a waxy appearance. There is generalized tympany, and on palpation a doughy resistance is felt. This large tumor is movable slightly in all directions and on manipulation causes the child to cry out. Some few superficial veins of the abdomen are dilated. The umbilicus is flat and continuous with the skin level. On percussion no fluid wave is transmitted.

**Laboratory Data: Urine.**—Straw, turbid, acid, specific gravity 1.021; albumen, heavy trace; sugar negative; acetone negative; casts hyaline 2 LPF coarse granular; 3 LPF fine granular; 5 LPF epithelium, few renal; pus cells occasional; mucus shreds occasional. An examination of the blood showed: hemoglobin 11 Gm., 65 per cent, color index 0.8; erythrocytes 4,300,000; leukocytes 4,350; S. lymph 24 per cent; L. mononuclears 8 per cent; polynuclears 64 per cent; eosinophils 4 per cent; juv. 4 per cent, stab. 2 per cent, seg. 58 per cent. **Preoperative Diagnosis:** Large intra-abdominal tumor with extreme pressure symptoms.

**Operation.**—January 26, 1937: Under ether anesthesia, a midline incision was made, which disclosed a large, slightly irregular mass which filled the entire abdomen. It was at first thought to be attached to the left broad ligament, but on more careful examination

it was found to be a tumor of the great omentum with a very small pedicle and slight vascularity. The attachment was just to the left of the midportion of the transverse colon. The tumor was easily delivered and the pedicle ligated close to the colon. The abdomen was closed. There followed an uneventful recovery with dismissal from the hospital on the thirteenth postoperative day.

*Pathologic Examination: Gross.*—Cystic, fluctuant tumor measuring approximately 170 Mm. in greatest diameter by about 120 Mm. in width and thickness. The outer surface is smooth but slightly irregular in contour due chiefly to the distribution of blood vessels. The site of attachment is slightly roughened. The tumor, on being opened, is found to consist of a single chamber which has a smooth, glistening lining, containing a watery, slightly yellowish-tinged fluid.



FIG. 1.—Photograph of the gross specimen of the lymphangioma of great omentum which was removed.

*Microscopic.*—Sections of the wall of the cyst show a somewhat hyalinized fibrous tissue. This is relatively acellular. In places the spaces between the fibers are infiltrated by lymphocytes and eosinophils. There are also small oval and elongated narrow channels in the thicker portion of the wall of the large cyst. These small spaces contain an amorphous eosin-staining substance. They are lined by long flattened cells which appear to be endothelial cells. Much of the inner surface of the large cyst is void of lining endothelial cells. This, probably, is the result of atrophy due to the presence of fluid within the cyst. *Pathologic Diagnosis:* Benign lymphangioma of the great omentum.

#### SUMMARY AND CONCLUSION

- (1) A rare tumor of the great omentum, lymphangioma, is reported. A careful search of the surgical literature reveals 53 to have been previously described.
- (2) A brief résumé of lymphangiomata, especially of the great omentum, is presented.
- (3) When confronted with an abdominal tumor in a child, one should not forget the possibility of lymphangioma of the great omentum.

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## LIVING FASCIAL SUTURE IN THE REPAIR OF LARGE INGUINAL HERNIAE\*

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SINCE the introduction of living fascial suture in the repair of inguinal herniae by McArthur, in 1901, very few surgeons have adopted this method either as a routine or as an occasional procedure. We feel that the operation has not received the acclaim that it deserves, since in all published reports the results have shown a striking improvement over other and more popular operations.

That the McArthur operation can be performed in conformity with the fundamental principles of the radical operations of Bassini, Halsted or Andrews is equally true, using, however, living fascial suture derived from the aponeurosis of the external oblique muscle, instead of absorbable or inert suture material. It is axiomatic, however, that large and especially direct inguinal herniae demand an unusually high individualization, so far as operative maneuvers are concerned. No one procedure is applicable to all herniae in this location, and many factors must influence the choice of operation. Nevertheless, an operation which will materially reduce the number of recurrences in the difficult cases should certainly be considered as possessing advantages in all cases, provided it does not increase the operative hazards and its performance is not beyond the technical ability of the average surgeon.

The use of fascia in operations for hernia was first reported by McArthur, in 1901, and there followed a second article, in 1904, in both of which he stressed the superiority of fascia over the ordinary suture materials. He made use of strips of fascia derived from the aponeurosis of the external oblique muscle and repaired the hernia according to the method of Bassini. He stated that other methods of suturing are dependent upon the development of cicatricial tissue between the sutured surfaces and that failure will inevitably develop in a number of cases because the cicatrix will yield to pressure. He demonstrated by microscopic sections that his autoplasic suture healed *in situ*, that it was not absorbed and did not slough.

Attempts to close a large defect in the floor of the inguinal canal, by ordinary methods, are not always successful. The use of catgut, kangaroo tendon, silk or linen affects adhesions, if successful, and many times the sutures must be applied under tension. It has been our experience that when ordinary

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sutures are applied under tension, they frequently cut through the sutured structures. Or, when they are absorbed, the weakness or defect recurs.

This is not true of fascia sutures. Gallie has shown that there is no inflammatory reaction excited, the fascia survives for years, if not indefinitely; it unites with the tissue in which it is embedded, has great tensile strength, and does not stretch under pressure as does scar tissue. The importance of this difference cannot be too greatly emphasized, because the support from the classic type of repair is as strong as the scar which unites the structures forming the floor and roof of the inguinal canal. The tendency of scar tissue to stretch and give way under pressure is, in most instances, the responsible factor in recurrences.

It may be stated as a truism that there are definite anatomic differences between the direct and the indirect hernia. These differences are much more fundamental than whether the hernia lies lateral or medial to the deep epigastric vessels. Robins has emphasized the deficiency of the structures at the pubic end of the canal in direct hernia, demonstrating the absence of a conjoined tendon, by the direct passage across the floor of the inguinal canal, of the internal oblique and transversalis muscles, leaving a defect at the lower end of the canal. In addition, the fibers of the lower border of these muscles have been shown to be weak and attenuated. The greatest defect is at the border of the rectus and from there it extends lateralward with a diminishing width, often as far as the abdominal ring. Because of this, the floor of the canal is often weak throughout its extent. The importance of repairing this defect cannot be too greatly emphasized.

The presence of a preformed sac in the indirect hernia has led certain surgeons, notably those of Great Britain, to practice high ligation of the sac and nothing further in the surgical cure of these cases. That this is sufficient many times, is attested by the large number of cured cases reported. However, its use has been restricted largely to children, and with this practice the writers are in accord. In the large indirect herniae, and particularly those which have existed for many years, the anatomic defect present closely resembles that which exists in direct hernia, namely, weakness and attenuation of the fibers of the internal oblique and transversalis muscles and a poorly developed conjoined tendon. Consequently, we feel that in all these cases, as well as in all direct herniae, fascial sutures should be employed in order to secure a larger number of permanent cures.

The incidence of recurrence following the radical operation for inguinal hernia varies somewhat, and there are many factors which must be considered in evaluating these statistics. Table I shows the percentage of recurrence from several representative clinics.

Table II shows the statistics which have been reported by several surgeons employing the McArthur technic or modifications of it. A study of these two tables will show a surprising superiority in the results obtained by the use of fascia suture over those using any other type of suture material, regardless of the operative procedure employed.

TABLE I  
INCIDENCE OF RECURRENCE

Author	No. of Cases	Dir.	Ind.	Recurrences Dir.	Recurrences Ind.	Percentage of Recurrences
West-Gibson-Cupp.....	828					7.24%
Page (London policemen).....				25.0%	20.0%	
Cumberlidge.....	517					8.7%
Andrews-Bissel.....	1,400			28.0%	20.0%	
Lyle.....	275	75	200	13.0%	9.0%	10.1%
Coley.....	837		837		18.0%	18.0%
Erdman (over 60).....	978			42.0%	10.0%	
Fallis.....	800	154	646	11.6%	7.4%	
Hoguet.....	1,212	249	963	6.8%	1.6%	
Lameris.....	613	102	511	28.4%	3.9%	
Druener.....	673	171	502	18.0%	5.0%	
Taylor.....	256	2,230		18.0%	5.6%	

We wish to report at this time our results in the performance of this operation; to discuss the technic of this procedure; and to report and analyze our failures. Unfortunately, we cannot report 100 per cent of cures, but we feel that we have significantly reduced the number of recurrences in dealing surgically with these difficult cases.

TABLE II  
INCIDENCE OF RECURRENCE FOLLOWING THE MCARTHUR METHOD

Arthur	No. of Cases	Dir.	Ind.	Recurrences
				Dir.
				Ind.
Robins.....	27	27		0.0%
Cambassis.....	25			0.0%
Keynes.....	100	45	55	0.0%
Lyle.....	154	54	100	9.0%
Cattell-Anderson.....	174	51	123	7.8%
				4.6%

Table III shows the results obtained in our operations upon 82 cases. Most of these cases have been examined postoperatively by one or the other of us, or by the family doctor. A few have reported by mail. As will be

TABLE III  
ANALYSIS OF 82 HERNIAE REPAIRED BY FASCIAL SUTURE  
*Authors' Series*

Total cases.....	82
Direct hernia.....	45
Indirect hernia.....	37
Bilateral hernia.....	8
Recurrent hernia.....	2
Recurrences.....	3
Direct.....	2
Indirect.....	1
Percentage of recurrences.....	3.6%

noted, we have had three recurrences. Let us first consider these recurrences individually.

ABBREVIATED CASE REPORTS OF THREE INSTANCES OF RECURRENCE

**Case 1.**—C. E., white, male, age 55, was admitted to the Chestnut Hill Hospital, May 24, 1931, for the repair of a right indirect inguinal hernia. The patient stated that the hernia had been present for many years and had considerably increased in size. Examination revealed a large indirect inguinal hernia, which was easily reducible. The internal ring was considerably dilated.

*Operation.*—May 24, 1931: A Bassini herniorrhaphy was performed, using the McArthur technic. Convalescence was uneventful and the patient was discharged, June 13, 1931.

Several weeks after returning home the patient's wife developed a cerebral apoplexy and the patient stated that it was necessary for him to carry her about. Shortly thereafter the hernia recurred. The undue effort indulged in by this patient so soon after operation undoubtedly was a contributing factor to the recurrence. At present time the patient is wearing a truss, which is unsatisfactory.

**Case 2.**—T. P., white, male, age 55, was admitted to Chestnut Hill Hospital, July 7, 1937. The patient stated that he noticed a "lump" in the left inguinal region about one year ago. Examination revealed a direct inguinal hernia.

*Operation.*—July 8, 1937: A Bassini herniorrhaphy was performed according to the method of McArthur. Convalescence was uneventful and the patient was discharged, July 30, 1937. He returned to work at the end of six weeks. Six months later the patient had a small recurrence at the upper end of the inguinal canal, in the region of the internal ring. This patient has subsequently been operated upon at another hospital.

This case emphasized the importance of securely closing the internal ring. Recently, we have adopted the method of suturing the external oblique beneath the cord, in order to afford greater stability to the floor of the inguinal canal and to reinforce the internal ring.

**Case 3.**—G. B., white, male, age 55, was admitted to Woman's College Hospital, May 17, 1936. He stated that he had had a rupture on both sides for several years. Examination revealed a bilateral direct inguinal hernia. Examination of chest revealed a chronic bronchitis.

*Operation.*—A bilateral inguinal herniorrhaphy was performed, according to the method of McArthur. There was a large defect present in the floor of the inguinal canal, on both sides, and considerable tension was placed on the suture line.

Postoperatively, the patient had an exacerbation of the bronchitis with persistent cough. He was discharged from the hospital in good condition, June 9, 1936.

One year later there was a recurrence on the right side, which we have recently repaired with a strip of fascia lata.

In retrospect, it is quite likely that it would have been safer to have repaired one side, then, after an interval of three months, to have repaired the other side. This would have lessened somewhat the tension on the suture line. Also, the exacerbation of the bronchitis and the persistent coughing undoubtedly were a factor in the recurrence in this instance.

*Operative Technic.*—The technic which we follow has been changed from time to time, as increasing experience has taught us certain important details.

The inguinal area is exposed through a long, oblique incision from the

anterior superior iliac spine down to the spine of the pubis. The aponeurosis of the external oblique muscle is divided, from below, upward, from a point just medial to the center of the external inguinal ring, to the point where the aponeurosis and the muscle blend. The hernial sac is handled in the classic manner, of high ligation. We prefer to transplant the neck of the sac beneath the internal oblique muscle.

A strip of fascia, about one-quarter of an inch in width, is then separated from the medial leaf of the external oblique aponeurosis. It is left attached at its lowermost point to the spine of the pubis. Its upper end is detached from the muscle fibers. The upper end is then threaded into the special "Vollrath atraumatic link for connecting fascial suture to the Gallie needle" (Fig. 1).

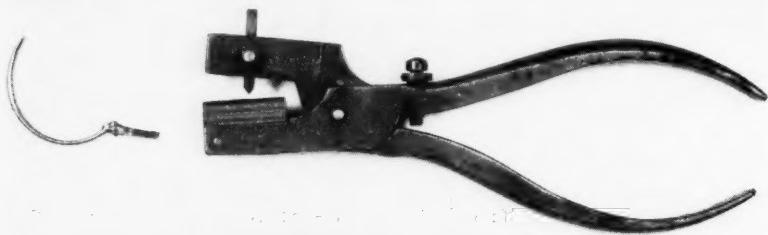


FIG. 1.—Vollrath atraumatic link for connecting fascial suture to the Gallie needle. The needle with attached link is shown, with the punch, used for attaching the fascia.

The first stitch is important, because it should obliterate the weakness at the lower end of the floor of the inguinal canal. The needle, with the attached fascia, is first passed through the conjoined tendon and then through the reflected portion of Poupart's ligament, known as the triangular ligament. This closes the lower end of the canal. The suture is then passed back and forth, uniting the conjoined tendon and the internal oblique and transversalis fascia, to the shelving edge of Poupart's ligament (Fig. 2). A goodly amount of tissue is included in each suture, which gives the effect of transplanting the structures rather than simply a suture line. We believe it advisable to fix each loop of fascia with a fine linen or silk suture to anchor it in place more securely. When the internal ring is closed snugly, the suture is fastened at its upper end either by splitting it and tying it in a double knot, or simply by suturing it with two encircling and transfixion sutures of silk or linen. It was formerly our practice to suture the external oblique aponeurosis over the cord. Recently, we have been suturing the aponeurosis beneath the cord, as we feel that this gives more stability to the repair. Catgut, silk or linen may be used for this purpose. We do not follow the original plan of McArthur who used a second strip of fascia to suture the aponeurosis. This we believe to be unnecessary. Occasionally, there may be some difficulty uniting the edges of the aponeurosis; in that case the cut edges may be sutured to the internal oblique muscle.

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This technic is applicable in practically every inguinal hernia. Occasionally, in recurrent herniae, the aponeurosis may be so shortened and adherent that it is unsuitable for use as a suture. In those cases the operations described by Gallie, Wangensteen and others are indicated.

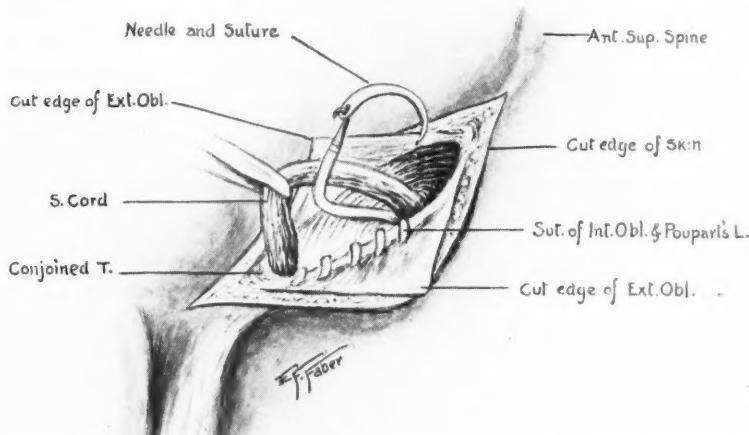


FIG. 2.—Showing the fascia suture in place, after the suture of the conjoined tendon and internal oblique to the shelving edge of Poupart's ligament.

## SUMMARY

- (1) Living fascia, in the repair of large herniae, is superior to all other forms of suture material.
- (2) The importance of closing the defect in the floor of the inguinal canal is discussed.
- (3) A comparison of the results of the McArthur technic, with other operations, clearly shows the superiority of the former method.
- (4) Our results, in the performance of this operation in 82 cases, are presented.
- (5) The technic which we follow is presented in some detail.

*Discussion.*—DR. S. DANA WEEDER (Philadelphia, Pa.): The problem of recurrence in the surgery of inguinal hernia falls under two headings—wound healing and dynamics.

Undoubtedly, the most important consideration in wound healing is infection. All those conditions, therefore, that favor infection should be avoided, such as leaving dead spaces, rough handling of tissues, blunt dissection, use of large and irritating sutures, burying of dead organic material, and the cutting off of blood supply by improper suturing. Under wound healing, there is ample reason to believe fascia to fascia secures a stronger union than muscle to fascia.

In considering dynamics, it will be observed nature provided an obliquity to the inguinal canal. This undoubtedly provides a stronger arrangement than if the internal abdominal ring and the external abdominal ring were in a

direct line with each other through the abdominal wall and there existed no obliquity to the canal.

In both types of operations, upon which the modern repair of inguinal hernia depends—the Bassini and the Ferguson—the new external ring is found superimposed over the site of the internal ring and the obliquity of the canal is lost. In the Bassini, the new site of the external ring is at the position of the internal ring, and in the Ferguson, the new site of the internal ring is at the position of the external ring. The site of recurrence after a Bassini is at the internal ring, and in the Ferguson at the external ring.

Two measures have been adopted, therefore, to strengthen these particularly weak areas. The fascia endo-abdominalis or transversalis fascia is used to repair the internal ring in indirect herniae, and in direct herniae it is used to strengthen the floor of the canal in the region of Hesselbach's triangle.

Finally, to restore the obliquity of the canal, I have sutured the aponeurosis of the external oblique, the internal oblique and transversalis muscles to the shelving edge of Poupart's ligament, *over* the cord, to a point midway between the internal ring and spine of the pubes. From that point down to the spine of the pubes those structures are sutured *beneath* the cord. The lower portion of the incised aponeurosis of the external oblique is now sutured over the cord to the point where the cord emerges; it is cut, fitted around the cord and sutured under the cord from there down. In this way, both weak areas, the site of the internal ring and of the external ring, secure the maximum strengthening and the obliquity of the canal maintained.

DR. L. K. FERGUSON (Philadelphia, Pa.): I have been employing wire sutures in herniae for about four years. In a series of about 142 cases, which I recently had an opportunity to review, there occurred five recurrences. My experience with the use of wire has led me to employ it almost to the exclusion of other suture materials, and I have not resorted to the use of fascia because wire sutures have proved so satisfactory. The reaction in the tissues with wire is less than obtained with catgut and even less than with silk. In all of these cases, with few exceptions, a local anesthesia has been used.

I have grown so confident in the strength and durability of wire sutures that I frequently allow the patient to be out of bed on the day after operation, if it is necessary for him to be erect to void without catheterization. As a rule, the patients are permitted out of bed on the third or fourth day after operation in cases of small indirect inguinal herniae. I believe that it is particularly important for patients to be allowed out of bed early if they are elderly. This measure has appealed to me as one of the most satisfactory for use in preventing postoperative pulmonary complications and phlebitis.

I find that, as Doctors Lehman and McCloskey have noted, recurrences occur almost invariably within the first year, and, as a matter of fact, in almost all cases within the first six months, or even within the first three months after operation.

DR. HENRY P. BROWN, JR. (Philadelphia, Pa.): There is one suggestion which I believe helps considerably in the prevention of recurrence of hernia, namely, to thoroughly remove the areolar tissue which covers the inner surface of the inguinal ligament before suturing the transversalis fascia, internal and external oblique muscles and conjoined tendon to the ligament.

This layer of areolar tissue may be regarded as having a function somewhat analogous to that of the oil in an automobile cylinder, in that when the oil is present the piston glides freely within the cylinder and when absent the piston sticks tightly to the cylinder. In a like manner, when this areolar tissue

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is allowed to intervene between muscle and ligament, firm union is much less apt to occur than when the muscles and fascia are brought into direct contact without the interposition of this areolar tissue.

I also find it advisable to place one or two sutures uniting muscle to ligament to the outer side of the cord. These are steps of precaution which I believe justify their use.

DR. J. A. LEHMAN (closing) : The average age of the patients was about 40. It has been our experience also that most recurrences occur a short time after operation; the three recurrences in this group occurred within one year. The patients in this series were all operated upon prior to 1938. I have no statistics on infection. We did have some, but I am sure the percentage was not very high.

DR. J. F. McCLOSKEY (closing) : I believe that fascial suture has a definite place in surgery as an adjunct in the treatment of hernia. An important factor in the cure of hernia is the position of the patient after operation. I use the semi-Fowler position, with the thigh flexed and the knees drawn toward the opposite shoulders. I believe when dealing with large herniae, and in old men, the best results are obtained by performing castration. One can, generally, obtain a cure even in the large herniae.

## USE OF WHOLE BLOOD AS A MEANS OF PREVENTING PERITONITIS AND ADHESIONS

A PRELIMINARY REPORT

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IN THE YEAR 1936, Jerusalem the "City of Peace" became the "City of Turmoil," for its hospitals were filled with patients suffering with all manner of gunshot wounds.

Emergency celiotomies were performed by day and by night; water in the sterilizers was kept constantly boiling, and numerous outfits for intravenous therapy were always in readiness. Many patients died; on the other hand it was remarkable how many patients recovered, even though their bowels were torn open in several places and even though fecal matter was found floating freely in the peritoneal cavity.

In particular, there was one patient who was very severely wounded in the abdomen and was brought in in a state of extreme shock. The descending colon had been torn across and the ileum was ruptured in two places, moreover the peritoneal cavity was filled with blood, and distributed about in the area of the torn colon was some considerable amount of feces. The injured viscera were repaired, the bleeding vessels ligated and the abdomen was closed without drainage. This patient made an uneventful recovery. This and other cases of a similar nature made a deep impression upon me.

It was difficult to understand how it was that these patients, flying, as it were, in the face of a potential peritonitis, had yet escaped without a severe fulminating infection and its logical sequence. What was the difference between these emergency operations, conducted under such unfavourable conditions, and the usual carefully conducted resection of the large bowel, which, in spite of the utmost precaution, so often ends with a fatal peritonitis?

It is obvious that, whereas, the systematic resection of the bowel is conducted in a perfectly dry field, these emergency operations were undertaken in a field swimming with blood.

There seemed no other essential difference between these two procedures, and it was felt that, possibly, the presence of the blood had had a beneficial effect and might have prevented the occurrence of peritonitis.

Accordingly, experimentations upon animals were carried out in an endeavour to substantiate the theory that fresh blood is capable of augmenting the natural defence mechanism of the peritoneum.

Before giving the results of these experiments it would be of interest to refer briefly to the bibliography of peritoneal immunity.

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*Previous Investigations of Peritoneal Immunity.*—Issayeff,<sup>1</sup> in 1894, found that the intraperitoneal injection of sterile irritants such as blood serum, broth, and NaCl solution increased the peritoneal resistance to bacteria. He found that these irritants were only moderately effective and at the same time there were local systemic reactions usually unpleasant and often severe.

Steinberg<sup>2, 3</sup> showed that satisfactory peritoneal protection is determined by three factors:

(1) A sufficiently large number of phagocyte cells must be mobilized to phagocytose invading bacteria and to prevent bacterial multiplication and elaboration of subtle toxic substances.

(2) Such a mobilization requires retention of the leukocyte-evoking antigen within the peritoneal cavity. Most antigens including ordinary suspension of bacteria leave the peritoneum too rapidly to be effective.

(3) Steinberg showed that a solution of gum tragacanth holding in suspension a prepared strain of *Escherichia coli*, treated by long exposure to a weak solution of formaldehyde, fulfilled these requirements.

Sparks<sup>4</sup> injected blood together with a broth suspension of bacteria into the peritoneal cavity of dogs. He found that autogenous blood together with varying types of pathogenic organisms injected into the peritoneal cavity of dogs did not predispose to the production of peritonitis.

Rankin, who previously had recommended intraperitoneal vaccination as a means of protection against peritonitis, has, in recent papers, definitely advised against this practice.

*Experiments upon Animals.*—In order to investigate the theory that free blood in the peritoneal cavity increases the resistance of the peritoneum against infection, it was necessary to produce peritonitis in animals. The experiments were divided into three categories:

*Group I:* The abdomen was opened and some feces were inserted into the peritoneal cavity and the wound was closed. This procedure was carried out on 10 rabbits and two dogs. Of these animals, only one died.

*Group II:* The abdominal cavity was opened and feces were inserted; in addition, the sigmoid colon was incised transversely and immediately closed by two rows of catgut sutures. This procedure was carried out upon five rabbits and seven dogs. Of these animals, all developed peritonitis but one, and this dog developed a paralytic ileus.

*Group III:* The same procedure as in Group II was carried out but in addition fresh blood was inserted into the peritoneal cavity. In the case of dogs, 50 cc. of blood were inserted into the peritoneal cavity.

*Method of Blood Injection.*—The abdomen was sutured in the usual way but a catheter was left at the angle of the wound. At this point a suture was inserted but not tied. Blood taken from the animal was mixed with citrate solution and then injected through the tube. The catheter was then withdrawn and the suture tied. Eight dogs were treated in this way. Of these animals, six survived. The two dogs who had died were examined and it was found that their deaths were caused, not by peritonitis but from a severe

infective necrosis of the abdominal wall; there were no adhesions in the peritoneal cavity of these two animals.

Several dogs of this group who did not die were afterwards sacrificed and the peritoneal cavities were found to be absolutely free from all signs of adhesions.

TABLE I

	Number of Animals	Number That Developed Peritonitis		Percentage
<i>Group I</i>				
Abdomen opened and feces inserted.	Rabbits 10 Dogs 2	1 0		10% 0%
<i>Group II</i>				
Abdomen opened, feces inserted and sigmoid incised.	Rabbits 5 Dogs 7	5 6		100% 85%
<i>Group III</i>				
Abdomen opened, feces inserted, sigmoid incised, and fresh blood injected.	Dogs 8	2		25%

It was found impossible to conduct these experiments upon pregnant animals since the resistance of the peritoneal cavity was so greatly reduced by the pregnancy.

**COMMENT.**—The extraordinary difference in the percentage mortality between Group I and Group II definitely proves that contamination of the peritoneal cavity with feces is not in itself sufficient to produce a fatal outcome. A superimposed injury or lowering of the vitality of the peritoneum must also be added.

Whether the evisceration of the bowel produces this injury or whether the opening of the colon itself provides this trauma is not at all clear. Possibly both factors acting together contribute to lower the peritoneal vitality and cause it to succumb to the bacterial infection.

The difference in the results between Group II and Group III would serve to indicate that free blood in the peritoneal cavity increases the resistance of the peritoneum by 75 per cent.

Two of the dogs in Group III who had died showed at autopsy that their deaths had not been caused by peritonitis inasmuch as they had died as a result of a severe infection of the abdominal walls with necrosis of the muscles and surrounding tissues. This infection was possibly the outcome of contamination acquired during the introduction of feces.

There seems to be a definite relationship between the presence of blood in the peritoneal cavity and the production of adhesions.

In Group II, in which feces were inserted without the addition of blood, the majority of the animals were shown at autopsy to have suffered with an intense peritonitis, with severe matting and adhesions of the bowels.

In Group III, in which feces were inserted together with blood, a totally different picture was shown. Here the peritoneal cavity was found to be

normal, and free from adhesions. When it is borne in mind that quite a quantity of feces was spread at random over the bowels, this absence of adhesions was quite remarkable.

*Clinical Application.*—As a result of these observations it was decided to apply this method to the treatment of peritonitis in human beings.

#### ILLUSTRATIVE CASE REPORTS

**Case 1.**—A young man was brought into hospital with the history of a duodenal ulcer that had recently perforated. Immediate celiotomy was performed under spinal anesthesia, and a large perforation was found in the duodenum, and the whole abdominal cavity filled with gastric content and in a state of intense inflammation.

The perforation was closed by means of a large catheter that suitably filled the orifice, and some omentum was sutured around the perforation. At the close of the operation a catheter was placed at the corner of the wound which was then closed. An untied suture passing through both peritoneum and fascia was inserted at the angle of the wound where the catheter lay. Two hundred cubic centimeters of blood were withdrawn from the patient and were mixed with 30 cc. of a 2 per cent sodium citrate solution. This blood was then run into the abdominal cavity and the catheter was withdrawn, and the loose suture tied. The patient made an uninterrupted recovery and has not since been troubled by the ulcer.

**Case 2.**—An elderly man was brought into the hospital, with the history of a duodenal ulcer that had perforated six hours previously. Operation, under spinal anesthesia, disclosed a condition of severe peritonitis. The ulcer was treated as in Case 1, and again 200 cc. of citrated blood were left in the peritoneal cavity. The patient had a smooth convalescence.

**Case 3.**—A man, age 72, was admitted to the hospital, in a condition of ileus, with a history of vomiting, much abdominal pain and a very greatly distended abdomen.

Operation, under spinal anesthesia, showed an abdominal cavity filled with pus, a very necrotic appendix, and a condition of ileus. The appendix was removed, the abdomen closed without drainage and 200 cc. of citrated blood were left in the abdomen. The patient made a very uneventful recovery, and left the hospital none the worse for his experience.

**Case 4.**—A young man was brought into hospital with a gunshot wound of the abdomen and in a condition of considerable shock. Intravenous saline therapy was instituted and an immediate celiotomy was performed. The jejunum was ruptured in four places, and there was a large hole in the descending colon with the extrusion of much feces. The abdomen contained a large quantity of blood. This patient, some days later, developed a severe ileus which was treated with the Miller-Abbott tube and spinal anesthesia with complete success.

#### CONCLUSIONS

As a result of experiments carried out upon dogs and rabbits, the following conclusions were arrived at:

(1) Infection of the peritoneal cavity with a small quantity of fresh feces does not of itself tend to produce peritonitis. This was found to be the case in almost 100 per cent of the experiments.

(2) Infection of the peritoneal cavity with a small quantity of fresh feces together with exposure and trauma to the bowel wall, did tend to produce peritonitis in 90 per cent of the experiments.

(3) The injection of free blood into the peritoneal cavity increases the immunity of the peritoneum against infection by over 75 per cent.

(4) The injection of free blood into the peritoneal cavity prevents the production of adhesion in a large percentage of cases.

My thanks are due to Professor Saul Adler, of the Hebrew University, for his valuable advice, and in whose department many of these experiments were carried out. Professor Bernard Zondek, also of the Hebrew University, very kindly permitted me to use his laboratories, and gave me much valuable advice.

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## THE INTRAVENOUS USE OF SERUM AND PLASMA, FRESH AND PRESERVED\*

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AND

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THE INTRAVENOUS USE of serum and plasma in place of whole blood is not new. The number of contributions on this subject has greatly increased in the last few years.

One of us has been interested in this problem intermittently since early 1927, at which time human serum was intravenously administered in cases of severe infections, especially those of streptococcal origin. It was noted then that the intravenous administration of serum in sufficiently large quantities (50 to 100 cc.) was commonly followed by reactions, often very severe, even when the sera were homologous, *i.e.*, caused no agglutination of the erythrocytes of the recipient. For serum, in this paper, is meant the fluid portion of the blood separated after clotting. Later (1929-1930), citrated blood was centrifuged and the plasma employed instead of serum. Primarily, this method was adopted because of its simplicity and its greater yield of the fluid portion. It was then noticed that the plasma, intravenously administered, caused no reactions, even when no attention was paid to typing. As a precaution the plasma was diluted with equal parts of saline solution before administration. We did not know at that time that this behavior of blood serum and blood plasma had already been observed and studied by Brodie,<sup>1</sup> as early as 1900. He found that, in cats and other experimental animals, the intravenous injection of blood serum, even autogenous, commonly produced reactions, which did not occur when similar quantities of sodium citrate plasma were used.

Of recent years, the intravenous injection of blood plasma in place of whole blood has been made the object of intense study by the Staff of the Bryn Mawr Hospital. Both serum and plasma have been used in infections,<sup>2</sup> in the prophylaxis and treatment of nutritional hypoproteinemia and anemias resulting therefrom,<sup>3</sup> in burns,<sup>4, 5, 6</sup> in certain hemorrhagic and hemolytic diseases, in preeclamptic states, in liver disease,<sup>7</sup> in chronic colitis, and, finally, in secondary shock.<sup>8</sup>

It is not the purpose of this communication to evaluate the clinical results of the use of plasma in the various conditions enumerated nor to discuss the

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rationale of whole blood transfusion, but rather to emphasize the simplicity of preparation and the safety in its use as compared to whole blood, and to make certain comparisons with the use of serum, both fresh and preserved.

The blood is collected in a closed system (Fig. 1), employing as an anti-coagulant 2 per cent sodium citrate solution in saline in proportion of 100 cc. for each 500 cc. of blood. The citrate-saline solution is first drawn into a

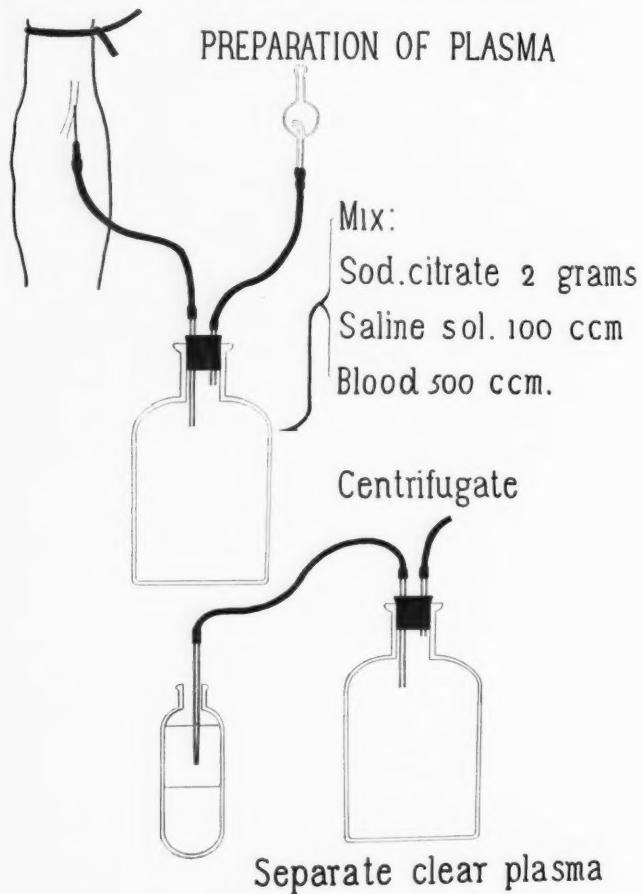


FIG. 1.—Showing the set-up for the collection of blood by a closed system.

liter pyrex flask by suction. The blood is then collected, using a rather large needle (No. 15-16 gauge) with the aid of slight suction. The flask is gently and continually rotated during collection, to insure thorough mixing of the blood with the citrate-saline solution. The plasma is separated by centrifuging the citrated blood for about one-half hour at high speed (2,000 r.p.m.). When considerable quantities of plasma are to be prepared, it is convenient to use a large centrifuge, holding four 250 cc. rubber-capped glass containers. The

opalescent supernatant plasma is removed by suction in a closed system and is stored at 4° C. The average yield of plasma is a little over 50 per cent of the citrated blood employed, not including the added citrate-saline solution. If the plasma is to be kept more than one day before being used, it is advisable to add "Merthiolate" 1:10,000 as preservative. On standing, there occurs, at times, a flocculent precipitate which is readily removed by short centrifugation. It does not, however, cause reactions if not removed. If the blood is collected after a meal, a buff layer of lipoid substance will, on standing, rise to the surface of the plasma. This material need not be removed, as it causes no reactions, and is easily resuspended by gentle shaking before administration.

Contrary to the statement of Lehman,<sup>9</sup> and others, it is not necessary, in our experience, to type the citrated plasma prior to the intravenous administration. Elliott<sup>10</sup> reached the same conclusion. As a rule we dilute the plasma with equal parts of saline or saline-glucose solution before injection, and regulate the speed of administration from 5 to 10 cc. per minute. When for particular reasons the bulk of fluids is to be limited, undiluted plasma may be safely administered. In such cases we regulate the speed of injection not to exceed 5 cc. per minute. The speed of administration does not seem to be, within certain limits, an essential factor, unless there exists a clinical contraindication. Undiluted plasma has been given in emergency cases at the rate of 8-10 cc. per minute without reaction. Viscosity of the material prevents administration at greater speed when the usual gravity method and a small size needle (No. 19-20 gauge) are employed.

Plasma thus administered has proved its complete safety and absence from reactions in over 1,500 administrations. One very important feature is that it can be given in very large and repeated doses. In one instance as much as 7,300 cc. were given in 11 days to a patient with severe burns, in an effort to maintain the serum protein concentration of the blood at a normal level. As much as 950 cc. of undiluted plasma were given as a single dose, followed immediately by 450 cc. of whole blood, without reaction. Intravenous injections of citrated plasma, fresh and preserved, have been repeated at intervals of three weeks, or longer, without reaction.

In 1935, Elser, Thomas and Steffen,<sup>11</sup> and, later, Flosdorf and Mudd<sup>12</sup> published reports on the procedure for the preservation in the lyophile form of serum and other biologic substances. Serum preserved in the lyophile form has been employed intravenously following regeneration with sterile water in the treatment of nephrosis by Aldrich, *et al.*,<sup>13</sup> and Jeans,<sup>14</sup> for the reduction of increased intracranial pressure by Hughes, *et al.*,<sup>15a, b</sup> and in hypoproteinemias by Ravidin.<sup>3</sup> It has been suggested from experimental work upon animals by Bond and Wright,<sup>16</sup> that the use of regenerated lyophile serum would be of benefit in hemorrhage and traumatic shock. Mahoney,<sup>17</sup> employing lyophiled plasma, reached the same conclusion after similar experiments. Thompson, *et al.*,<sup>18</sup> used lyophiled plasma to prevent hypoproteinemias and wound disruption in experimental animals.

Intravenous administration of lyophiled serum is often followed by reactions. Thus, Aldrich, *et al.*,<sup>13</sup> noted reactions to intravenous administration of lyophiled serum, which in two out of nine cases were severe and accompanied by chills and high temperature. Lehman<sup>9</sup> reported reactions with similar material, as does Ravdin.<sup>3</sup> In our experience, the intravenous administration of lyophiled serum has often been accompanied by severe reactions, even with as little as a 5 cc. dose. These reactions have been generally attributed to a change induced in the serum by the lyophile process. Our experience with fresh serum, related above, led us to investigate the use of lyophiled plasma. Citrated plasma, separated in the manner above mentioned, and lyophiled by the method of Flosdorf and Mudd,<sup>19</sup> was regenerated with sterile water to restore its original volume and administered intravenously to patients in quantities up to 100 cc. without reactions. This material was then employed in greater quantities in isotonic form and also in the hypertonic form, *i.e.*, concentrated as much as five times, still without reaction. The following is an abstract of a typical case:

**Case Report.**—A white woman, age 82, weighing 63 Kg., was admitted to Bryn Mawr Hospital with amebic dysentery. During the convalescence the patient developed hypo-albuminemia, with generalized pitting edema and oliguria. She was given, intravenously, citrated, lyophiled plasma regenerated with distilled water to only one-fifth of its original volume (125 cc., corresponding to 625 cc. of undiluted plasma). The lyophiled material had been preserved for several months. The plasma was administered by the drip method, during a period of 20 minutes. There was no reaction. The urinary output exceeded the intake for a period of three days following the administration of plasma. Within 48 hours, the edema had disappeared and in six days, when again checked, the blood albumin concentration rose from 2.6 Gm. per cent to 3.2 Gm. per cent.

In other cases, concentrated lyophiled plasma was administered at even greater speed, up to 110 cc. of five times concentrated solution (corresponding to 550 cc. of undiluted citrated plasma) in six minutes, without reaction. It is to be noted that concentrated lyophiled plasma appears as an opaque, amber, viscous fluid and that, to obtain the speed of transfusion mentioned above, a syringe must be used. We do not advocate rapid administration except in emergency cases, but we report it to emphasize the safety of the material. The method of choice for injection is the drip method, at a rate of about 4-5 cc. per minute.

**COMMENTS AND DISCUSSION.**—It may be accepted as a fact that intravenous administration of serum, fresh or preserved by the lyophile process, is often followed by severe reactions. These reactions were not encountered, in our experience or in that of other workers, *etc.*,<sup>4, 5, 10, 20</sup> when citrated plasma, separated by centrifugation, is employed, fresh or preserved, either by refrigeration or by the lyophile process. We do not intend to discuss the physiochemical differences between the serum and plasma responsible for the mentioned difference in behavior. We may assume, with Brodie,<sup>1</sup> that the difference is brought about by the process of fibrin precipitation. Reactions often

occur when citrated blood in which, accidentally, clotting has taken place, is injected intravenously. Filtration to eliminate blood clots does not prevent reactions.<sup>26</sup>

It is unfortunate that, in many reports, the terms "serum" and "plasma" appear to be used interchangeably. For instance in the article of Mahoney,<sup>17</sup> Bond and Wright<sup>16</sup> are quoted as having employed lyophiled plasma. Bond and Wright used lyophiled serum only in their investigative work.<sup>21</sup> Similarly, McClure<sup>6</sup> appears to use the two terms interchangeably.

In the ordinary type of hospital the lyophilizing of plasma is not necessary, due to the fact that plasma keeps well under ordinary conditions of refrigeration (about 4° C.) for several months, except when used for its prothrombin and complement content. The content of specific antibodies in the plasma remains unchanged for at least 32 days;<sup>22</sup> the complement activity begins to decline only after the third and fourth week,<sup>22</sup> in a manner similar to that reported for refrigerated blood.<sup>23</sup> The period of useful survival of prothrombin was found to be one week to ten days,<sup>22</sup> similar to that found for the refrigerated blood by Rhoads,<sup>24</sup> and Lord.<sup>25</sup>

Plasma preserved at 4° C. has been employed successfully after 40 days, in the treatment of secondary shock<sup>8</sup> and various forms of hypoproteinemias. It is presumed that blood plasma can be preserved by refrigeration for much longer periods of time. Thus, plasma has been kept for three to four months in the frozen state, and then employed intravenously, without reaction. Refrigeration at 4° C. is probably as effective as freezing as a means of preservation, but technically much simpler.

In the Bryn Mawr Hospital, the plasma is a by-product of the blood bank. Experimental data<sup>22</sup> suggest that refrigerated blood is useless, occasionally dangerous, after five days of preservation. Citrated blood after five days of storage is centrifuged, the plasma pooled, dated and preserved. This keeps a fresh supply on hand for use in the conditions outlined previously. The lyophile method of preservation would, obviously, be of value in isolated hospitals, in cases of emergency in outlying districts, involving field work; disasters of many sorts, such as fires, flood, earthquakes, war, etc.,<sup>20, 27</sup> and for cases in which hypertonic plasma is indicated. We have employed lyophiled plasma kept for a period of ten months without reactions; it can, in all probability, be kept for a much longer period of time.

#### CONCLUSIONS

The intravenous use of citrated blood plasma without cross-matching is both safe and convenient. This applies to fresh plasma, or plasma preserved by either refrigeration at 4° C. or the lyophile process. Serum, separated after clotting, may cause reactions, often severe, when intravenously injected, whether employed fresh or preserved by either refrigeration or the lyophile process.

Appreciation is expressed to the Staff of the Bryn Mawr Hospital for their helpful cooperation and, especially, to Dr. D. D. Bond for valuable aid.

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## FUNDAMENTAL FACTORS GOVERNING LYMPHATIC SPREAD OF CARCINOMA

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THE LYMPHATIC spread of carcinoma is generally spoken of as a permeation or embolism through an afferent lymph channel, involvement of the lymph node, spread through the node into the efferent lymph channel, and a repetition of the process through nodes until the thoracic duct is reached. Sampson Handley,<sup>1</sup> studying advanced lesions, was an advocate of the permeation theory. Ewing<sup>2</sup> recognizes the process of permeation but maintains that much of the spread must be by embolism. An important surgical aspect of this question is the manner of spread, once a node is involved, and the significance of finding involved nodes at the time of operation.

A very careful study of the lymph node metastases in 74 operative specimens of carcinoma of the rectum and colon was made. This was done by clearing the specimens as described (Gilchrist and David).<sup>3</sup> Full scale drawings of all specimens with the arterial tree and the exact location of the lymph nodes in relation to the tumor and arteries were made. About 3,500 different lymph nodes were studied and microscopic sections were made. Three hundred sixty-four of these nodes contained carcinoma metastases. In addition, Dr. C. W. Monroe has allowed me to review 651 microscopic sections of lymph nodes studied in a similar fashion in operative specimens of carcinoma of the breast. There were 118 of these nodes which contained metastases. A study of our material has led me to the conclusion that the lymphatic spread of carcinoma is primarily embolic, and that the nodes where emboli lodge prevent further spread until the node is completely overwhelmed by carcinoma. Further embolic spread is through the collateral lymph channels, each new node involved tending to make a longer channel for a new embolus to travel. Spread from one node to another is not common, at least during the period when lesions are seemingly operable.

In order to understand the factors governing the spread of carcinoma through the lymphatic system, let us examine its structure. The lymph is collected into thin-walled elastic channels which run for a variable distance from their origin in the structure to be drained to the lymph nodes. The nodes and lymph channels tend to lie in close proximity to the blood vessels supplying the region. The nodes are made up of a capsule, thick or thin, or the small nodes of the mesentery may have no capsule, but there does seem to be a definite boundary between the lymphoid tissue and the surrounding fat. In those nodes containing a capsule the collecting lymph channels pierce the capsule and discharge their contents into the subcapsular space which lies between the capsule and the lymphoid tissue. The center of the node has a connective

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tissue framework, the reticular cells. The larger nodes are divided into gross compartments by connective tissue trabeculae leading from the capsule to the hilus of the node. The lymph cells are found between the reticular cells. There are many collecting lymph channels entering each node. I have repeatedly made injections directly into ten to 14 different afferent channels entering one node in a dog's mesentery. These, of course, all empty into the subcapsu-

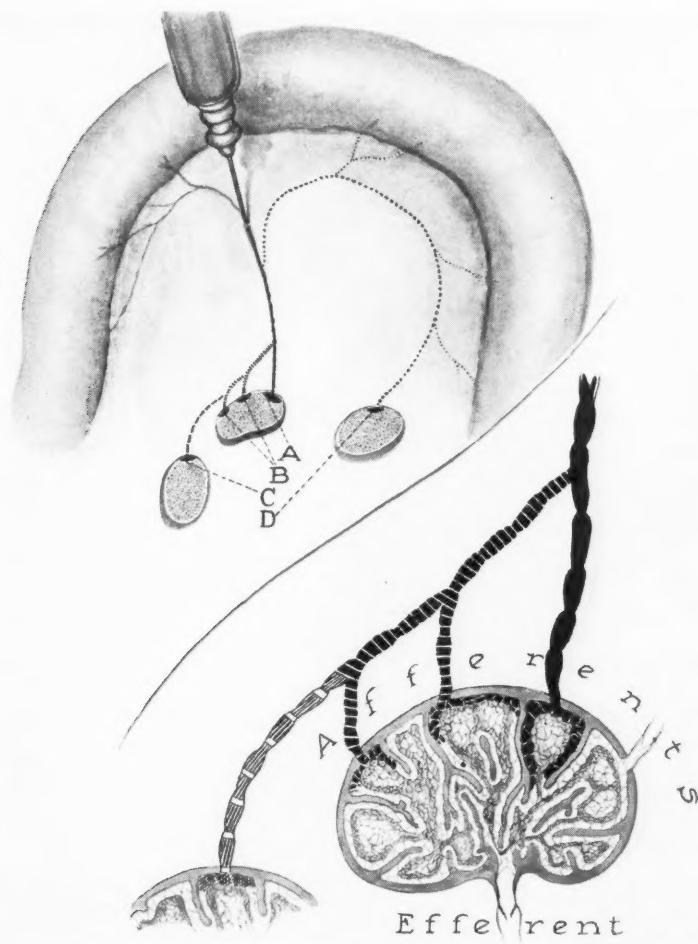


FIG. 1.—Showing the manner of spread of a suspension of insoluble particles injected into a single afferent lymph channel.

lar space. Many large afferent lymph channels break up into two, three, or more short channels just outside the node, and then these shorter channels pierce the capsule to empty into different parts of the subcapsular space, or one of the short channels may empty into the lymph sinus of an adjoining node. In addition, there are usually several different anastomosing channels between the large afferent channels draining a given region of the bowel, and the channels draining into adjacent nodes on either side (Fig. 1).

When a colored solution is injected into an afferent lymph channel of a dog's or rabbit's mesentery, using very low pressure, the solution will penetrate through the node without coloring all of it. The node seems to be divided grossly into separate anatomic units so that material from a given channel seems to drain to a limited part of the node. When pressure is used in the injection, the entire node will be colored before any dye appears in the efferent channel. If, instead of a colored solution, a suspension of carbon particles  $\frac{1}{2}$  to  $1 \mu$  in diameter, or of silica which is less than  $\frac{1}{2} \mu$  in diameter, or a suspension of barium or carmine particles is used to inject into the afferent



FIG. 2.—Photomicrograph of lymph node almost completely replaced by carcinoma metastases. The normal parts are seen as dense, finely granular areas. A suspension of carbon particles was injected into the lymph channels in the neighborhood of the carcinoma of the breast. Most of the carbon is seen in the normal part of the node, although some of it penetrates a short distance along spaces between the cancer cells. A part of the lymph sinus which is involved with carcinoma also contains carbon particles. Two areas of fatty degeneration are seen.

channel using very low pressure, a different picture is seen. The suspension of colored particles will partially fill its own compartment in the subcapsular space (Fig. 1 A). If more pressure is used, the suspension will either overflow into the remainder of the node or it will enter the adjacent parts of the node through one of the short channels leading into a different part of the subcapsular space (Fig. 1 B). If there is much pressure, the node is soon a solid black and the suspension may pass into one or even two or three of the adjoining nodes through the short channels (Fig. 1 C). At the same time it may back up one of the tributary channels emptying into the original channel injected and it is often possible to get it to go through a retrograde anastomosing channel and come through another afferent channel into an adjoining normal node (Fig.

I D). Even great pressure to the point of rupturing the walls of the afferent channels will not force any one of the fine suspensions through the node. If the animal is killed immediately or is allowed to live for a week and then killed, no sign of passage through any node is seen, either in transparent preparations or in microscopic sections.

This demonstration of the collateral drainage is made easier by blocking the afferent channels of one node with sodium morrhuate three or four days before injection with the colored suspension. The blockage will cause a dilatation of the collateral channels. This experiment shows very graphically

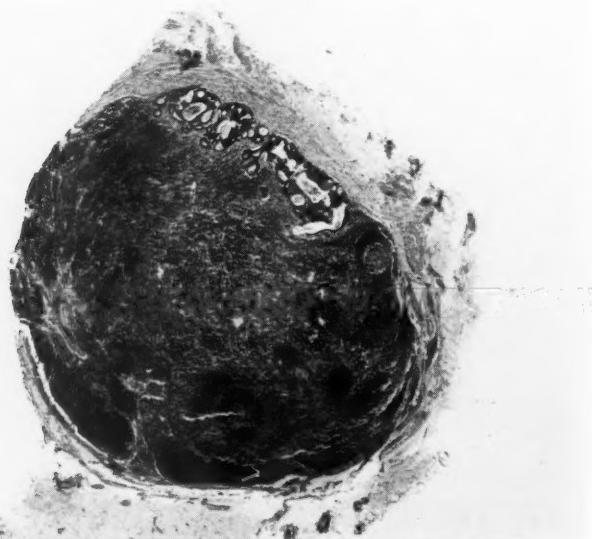


FIG. 3.—Photomicrograph of a carcinoma metastasis confined to the subcapsular space.  
The thickened capsule over the region of the metastasis is clearly seen.

how, when a node is destroyed or blocked, the lymph drainage is rerouted through collateral channels, or by retrograde means, into a channel draining into a normal node. Carcinoma cells are  $7 \mu$  or more in diameter in contrast to these particles, which were all less than  $1 \mu$  in diameter. The normal system of collateral lymph channels, plus the demonstration of retrograde channels available when nodes are blocked, shows how much more likely spread of the large carcinoma cells is apt to be by collateral channels than by growth through lymph nodes.

A study of our surgical material has brought out the following facts:

(1) Permeation of carcinoma through lymph channels was seen only when the lymph node central to the channel involved was already blocked with carcinoma.

(2) Carcinoma metastases do not completely destroy the function of a node until all of the node is destroyed. This was shown in a surgical specimen of carcinoma of the breast. The lymph channels in the neighborhood of the

tumor were injected with a suspension of carbon particles. The specimen was cleared and some of the lymph channels and several lymph nodes were seen to be outlined in black. This section shows how the carbon suspension could still flow into a node which contained a large metastasis. Most of the carbon is found in the normal part of the node although some of it penetrates a short distance along spaces between the cancer cells (Fig. 2).

(3) Forty-four of the 364 carcinomatous nodes contained metastases limited to the subcapsular space just beneath the capsule (Fig. 3). In 150 of the 364 involved nodes, the lymphoid tissue was completely replaced by carcinoma.

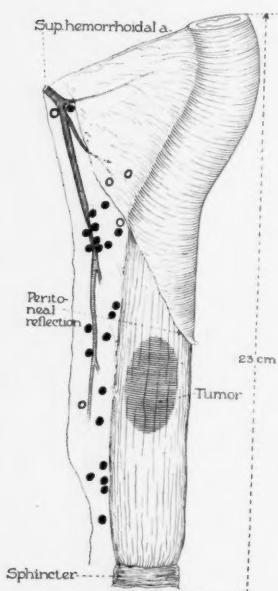


FIG. 4.—Path. No. 33779: Operative specimen showing almost complete occlusion of superior hemorrhoidal artery by a mass of necrotic carcinomatous nodes. In some of the tightly packed nodes the carcinoma had penetrated through the capsule.

likely to be completely replaced by carcinoma. The group of heavily involved nodes is along the main or primary line of lymph drainage. Nodes involved below or lateral to these nodes are apt to be subcapsular lesions or ones which are obviously late metastases.

(5) In no case has there been any evidence of penetration of carcinoma outside of the capsule of any node, except where there was a collection of large involved nodes lying tightly packed together. In seven of the nine cases where this occurred, the superior hemorrhoidal artery or the main artery supplying the region of the nodes was blocked by pressure of the nodes. Several of these nodes contained necrotic material.

(6) In six cases, retrograde metastasis of lymph nodes was found below

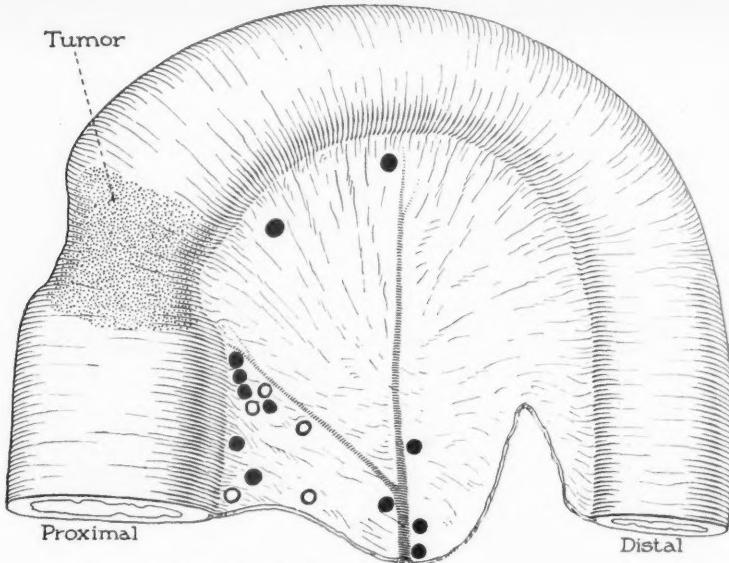


FIG. 5.—Path. No. 33730: Example of extensive metastases to central lymph nodes, apparent lymph blockade, and metastasis in a retrograde manner to a node distal to the lesion.

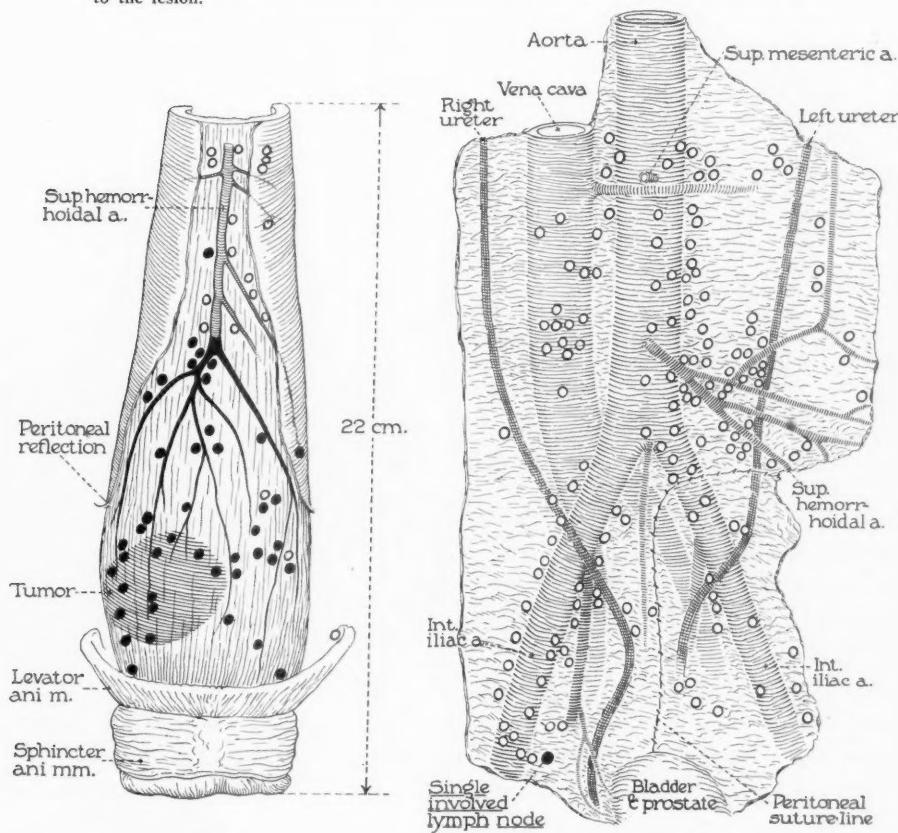


FIG. 6.  
FIGS. 6 and 7.—Path. No. 36303: Figure 6: Operative specimen of the rectum showing extensive lymph node metastases above the tumor, and diagram of the autopsy preparation showing limitation of the upward metastasis. Figure 7: The one node involved was just outside of the operative field—and it was a small subcapsular lesion.

carcinomata of the bowel or rectum. In every one of these enough of the nodes central to the lesion were completely replaced by carcinoma to make us feel certain that there was a very marked obstruction to lymph flow and the metastasis was by retrograde means (Fig. 5).

(7) Postmortem examination of surgical patients demonstrates the tendency of the lymph nodes to block the spread of carcinoma even in advanced cases. In four cases, where the patients died within two weeks after resection of the rectum or sigmoid for carcinoma, microscopic sections were made of all

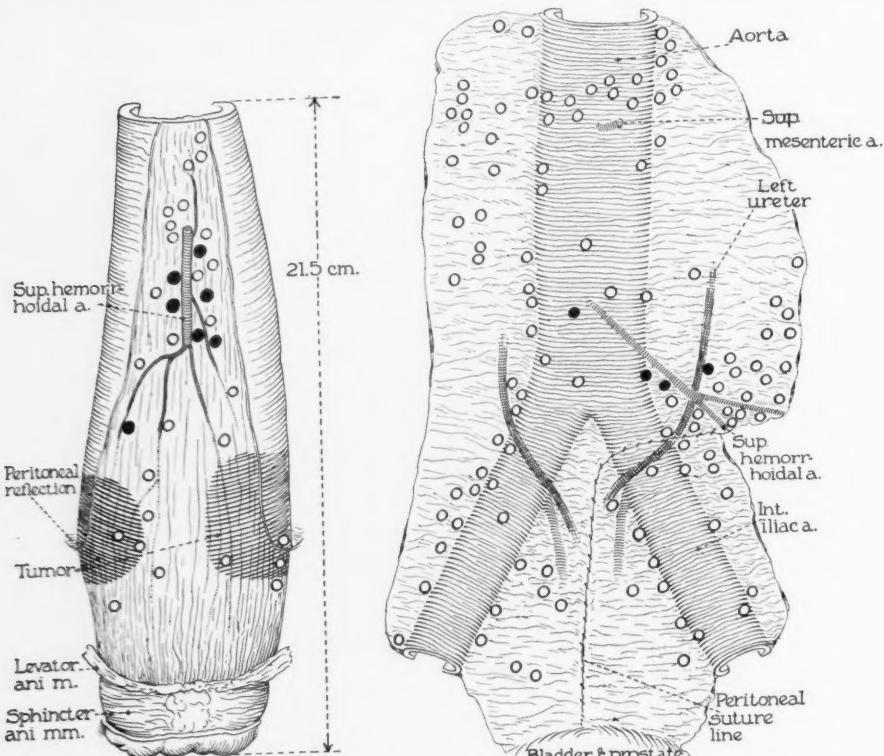


FIG. 8.

FIG. 9.

Figs. 8 and 9.—Path. No. 36642: Figure 8: Operative specimen of extensive, high lying lymph node involvement, and autopsy preparation. Figure 9: The three nodes near the line of resection of the superior hemorrhoidal artery could not be resected at this site because of a congenital peritoneal anomaly. The highest node involved showed only a small subcapsular metastasis.

of the retroperitoneal nodes from above the point of origin of the superior mesenteric artery to the inferior border of the prostate, as far distal as it is possible to cut the arteries from within the abdomen. Each of these preparations contained 110 to 168 lymph nodes. The one patient who had no metastases in his operative specimen also had none in the 110 abdominal nodes examined. In the second patient (Fig. 6) 43 of the 62 nodes found in the surgical specimen contained metastases. In spite of the extensive lymph node involvement in the operative specimen (Fig. 7), there were no metastases above the point of resection. The one node involved was about 1 cm. lateral to the widest point of resection, along the superior surface of the levator ani

## LYMPHATIC SPREAD OF CARCINOMA

muscle. This is the second route of lymphatic metastasis in carcinoma occurring at the level of the levator ani muscle. The third patient was a man 72 years of age. There were a number of enlarged nodes high up (Fig. 8). Because of a peculiar congenital peritoneal anomaly the superior hemorrhoidal artery could not be resected as high as it usually is. Thirty-five nodes were

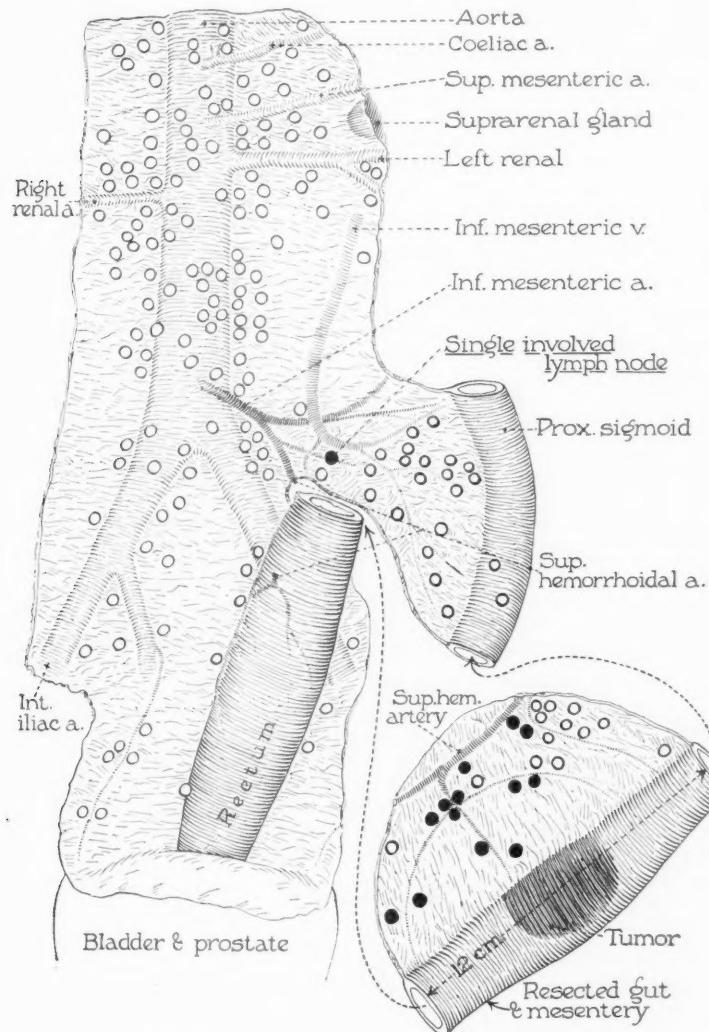


FIG. 11.

FIG. 10.

Figs. 10 and 11.—Path. No. 37719: Figure 10: Operative specimen of carcinoma of the rectosigmoid having a very large mass of involved nodes close to the line of resection. Figure 11: Autopsy specimen showing a small subcapsular metastasis in a node just beyond the line of resection.

found in the operative specimen, seven of them contained carcinoma. The diagram of the postmortem preparation (Fig. 9) shows the location of the 111 nodes studied. The four nodes found to be involved at postmortem are marked. The three nearest the tumor were heavily involved with carcinoma

and would probably have been removed except for the congenital anomaly. The fourth postmortem specimen was from a man 66 years of age. The lesion was just above the rectosigmoid. It was the size of a fist and there was a large mass of nodes up to the promontory of the sacrum. A David<sup>4</sup> type of obstruction resection was performed (Fig. 10). Many of the involved nodes seen near the highest point of resection were completely destroyed by carcinoma (Fig. 11). Only one of the 168 nodes found in the postmortem preparation contained carcinoma, and that was a very small subcapsular metastasis. None of these four patients had demonstrable metastases either in the liver, lungs or elsewhere at postmortem.

#### CONCLUSIONS

- (1) The normal lymph node of a rabbit or dog will not pass a suspension of insoluble particles  $1 \mu$  or less in diameter even when pressure of 120 cm. of water is used. The coloring of a number of adjacent nodes by the particles following injection into a single afferent lymph channel is explained by the anatomic distribution of collateral or retrograde lymph channels.
- (2) Permeation of carcinoma through lymph channels is not the usual manner of spread in early lesions.
- (3) Nodes partially involved by carcinoma may still function.
- (4) Many metastases to lymph nodes are confined to the subcapsular space.
- (5) Groups of lymph nodes involved with advanced metastatic lesions tend to be found in certain regions. Retrograde metastases are found only when the nodes in these regions are heavily involved. Metastases in nodes below or lateral to the main lymph drainage are apt to be subcapsular lesions or obviously late metastases.
- (6) Spread of carcinoma through the capsule of a node is rarely seen in surgical specimens, and then only in lesions having a mass of heavily involved nodes packed together. The blood supply to the nodes is usually interfered with in such cases.
- (7) Postmortem examination of surgical patients demonstrates the tendency of the lymph nodes to block the spread of carcinoma even in advanced cases.

All of these facts lead us to the conclusion that the lymphatic spread of carcinoma is primarily embolic. The nodes where the emboli lodge prevent further spread until the node is completely overwhelmed by carcinoma. Further embolic spread is through the collateral channels, each new node involved tending to make a longer and more difficult channel for a new embolus to travel. Spread from one node to another does not seem to be common, at least during the period when lesions are operable. Thus the finding of a group of involved nodes within the field removable by surgery does not mean that such a case is hopeless, although the chance of complete removal is much less than in those where such nodes are not found.

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## METABOLIC AND BLOOD CHEMICAL CHANGES IN A SEVERE BURN

### CASE REPORT

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INASMUCH as few complete chemical and metabolic studies have been made clinically in severe burns, the following case report seems of significance.

**Case Report.**—The patient, white, male, age 27, was severely burned by gasoline which exploded, setting fire to his clothes. A local physician immediately sprayed the burned area with tannic acid. He also received numerous hypodermics for pain as well as moderate amounts of whisky. He was admitted to the St. Louis City Hospital, 48 hours later, January 3, 1938, on the third day after the accident. During his first month's hospitalization, he had the services of three special nurses, which enabled an accurate measurement of intake and output; much of this data is presented in Chart 1. Further details of his course and treatment are described herewith. Although this report represents only 30 days of his illness, the patient remained in the hospital for several months but eventually made a complete recovery. Most of his later therapy concerned the skin grafting of the burned area.

**Clinical Course.**—The patient was conscious and rational on entrance and remained so until the sixth day after the accident. The blood pressure was 150/110 on the seventh day and reached the high mark of 182/120 on the twelfth day. It remained about 160/120 until the nineteenth day when it suddenly dropped to 130/80 and then stayed there except for an occasional rise to 150/90. From the sixth to the seventeenth day he was more or less drowsy most of the time, and vomited one or more times every second or third day. He became comatose on the twelfth day. Muscle twitchings were observed on the eighth and twelfth days. Cheyne-Stokes breathing was noted on the twelfth day. With the high blood pressure on this day, the clinical picture was that of "pseudo-uremia." The patient became rational and alert on the seventeenth day and remained so from then on.

It was estimated that about 40 per cent of his body had been burned, *i.e.*, the entire circumference of both legs up to the groin, both buttocks, a small part of the lower abdomen and the distal thirds of both arms. Nearly all of the burn was third degree as shown by the granulating areas which were eventually revealed under the crust. Indeed, in many places over the thighs fascia lata and muscle were involved. The tanned areas were gradually débrided whenever infection was evident or suspected. The débrided, granulating areas were covered with saline packs. Eventually the crust was entirely removed and the unhealed granulating areas were skin grafted.

**General Therapy.—Diet:** The patient was given a diet of 2,000 calories every day; of this, the daily protein comprised 40 Gm. (6.3 Gm. of N) the first 12 days, 80 Gm. (12.0 Gm. of N) the next six days, and 120 Gm. (19 Gm. of N) the last 12 days. Vitamin B was given in the form of Betalin tablets and brewers' yeast. Ample amounts of the other vitamins were also administered. Transfusions (500 cc. whole blood) were given every third or fourth day (see chart at points marked T).

**Fluids.**—The patient received 4,000 to 6,000 cc. of fluids per day up to the tenth post-entrance day and during the eighteenth to thirtieth days; between the tenth and eighteenth

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## METABOLISM IN BURNS

days the amount was increased to 6,000 to 11,000 cc. As much as possible was given by mouth, but it was necessary to supplement it each day with subcutaneous saline and intravenous glucose. Continuous venoclysis was begun on the seventh postburn day and terminated on the sixteenth day. We believe that the high fluid intake and output was of great therapeutic value. It will be noted that during the peak of fluid intake and diuresis the blood N.P.N. fell significantly (tenth to eighteenth day).

*Drugs.*—Adrenal cortex extract was used in burns by Wilson, Rowley and Gray.<sup>1</sup> In experimental burns, it was used by Einhauser,<sup>2</sup> who reported a favorable effect on mortality. In this patient, it was used largely to increase urinary output because anuria is common to both adrenal insufficiency and severe burns. A dose of 5 cc.\* was given on the fifth and eighth days and 10 cc. during the sixth and seventh days (intravenously). The administration was terminated because there was some doubt as to whether the drug was having any effect in increasing the urinary output which, indeed, was never very low.

Sulfanilamide was given by mouth largely because of the extensive local infection about the buttocks. A dose of 60 gr. per day was given during the sixth to twelfth days; thereafter it was reduced to 30 gr. per day up to the twenty-first day, when it was discontinued. Morphine, codeine, and aspirin were given as needed for pain and insomnia.

*Laboratory Data* (see also Chart 1).—The chemical methods used were all standard except for blood diastase which was determined by the procedure described by Somogyi.<sup>3</sup> It should be noted that protein metabolism has been discussed and the data presented in terms of nitrogen intake and output.

*Examination.*—The red blood count was 7,000,000 on entry (third postburn day). The count gradually dropped to 3,500,000 on the fourteenth postburn day and then varied from 3,500,000 to 4,500,000.

The patient became jaundiced on his seventh postburn day and had an icteric index of 80. At the same time the urine showed a strongly positive test for urobilin and a trace of bile (the latter for one day only). It is interesting to note that the red blood count dropped to 4,500,000 on this day, whereas, it was 7,000,000 three days previously. The icterus was probably not obstructive but either of hemolytic or hepatogenous origin.

The white blood count was 40,000 on entry and reached the high total of 82,000 on the twelfth day. After this, the count varied from 50,000 to 35,000 until the thirtieth day when it dropped to 30,000. The count was 20,000 on the forty-ninth day and 14,000 on the seventieth day. During the first 30 days, differential counts showed many immature cells. One particular smear, on January 12, 1938, showed juveniles, myelocytes, and promyelocytes. Some plasma cells were seen. At no time was there a palpable spleen or a generalized lymphadenopathy.

The nonprotein nitrogen of the blood (in mg. per cent) ranged from 43 to 48 for first 11 days, then gradually dropped to 30 by the fifteenth day. At this time patient was receiving 11,000 cc. of fluids daily. The protein intake was doubled at about this time and the fluids were gradually decreased to 4,000 cc. per day; following this, the nonprotein nitrogen rose to 40 on the eighteenth day and stayed near this level until the twenty-fifth day, when it dropped to 30. Later it dropped to 19 (normal).

Serum protein was 4.9 Gm. per cent at entry (third postburn day). However, the serum protein rose above the edema level in several days and stayed between five and six throughout the whole month. There was a reversal of the albumin-globulin ratio due to a progressive loss of the albumin fraction. There was no tendency to develop edema at any time. The blood diastase remained normal.

The blood cholesterol remained low for first 28 days, dropping as low as 87 mg. per cent on the seventh day. This is compatible with a high basal metabolism. The high metabolism is consistent with the increased destruction of proteins as shown by the high output of nitrogen in the urine. The patient lost weight rapidly in spite of a high caloric.

\* The adrenal cortical extract was generously supplied by the Upjohn Co.

high protein (120 Gm.) diet. The creatinine nitrogen (an index of the endogenous protein metabolism) was taken once and was found to be high (2.3 Gm. per 24 hours). The basal metabolic rate was not taken.

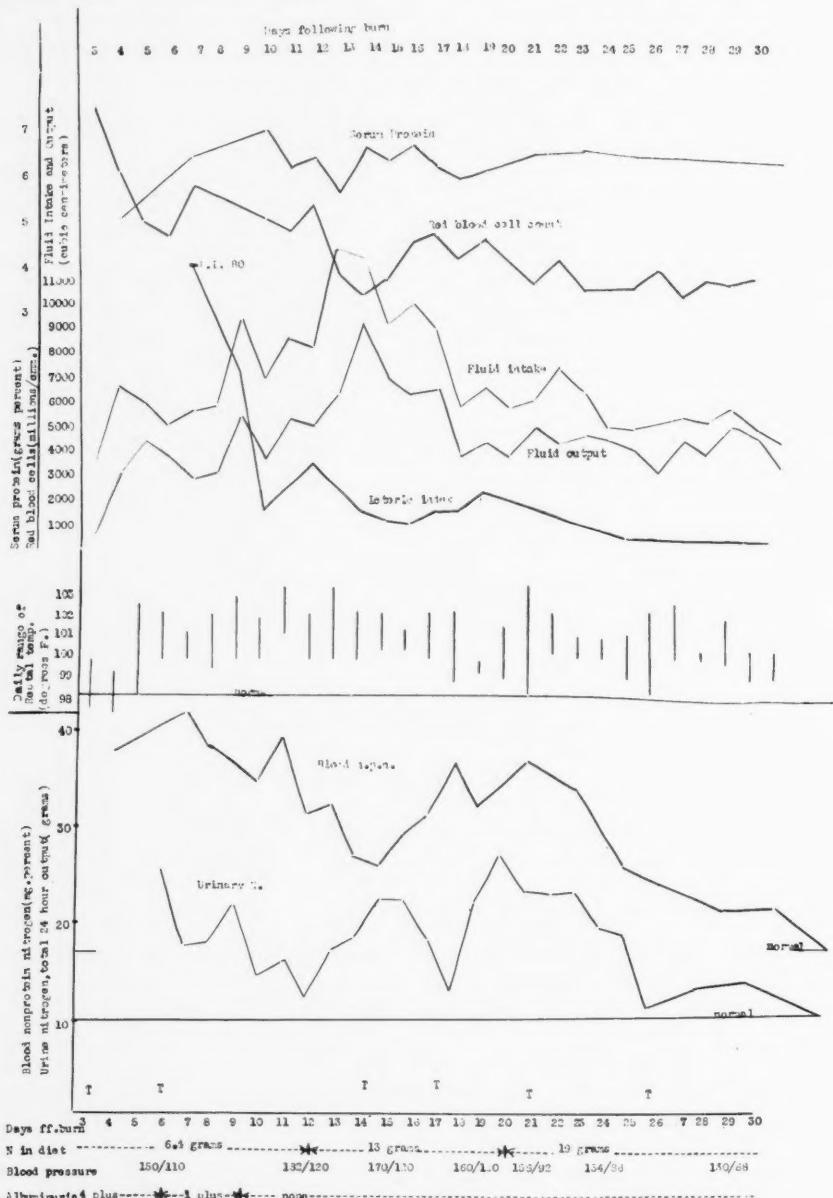


CHART 1.—Chemical and metabolic data as described in the text. Abb: I.I. = Icteric index. T = Transfusions of 500 cc. of whole blood. N.P.N. = Nonprotein nitrogen.

*Urine.*—Albuminuria was present (four plus) the first seven days, dropped to a one plus on the eighth to eleventh days, but thereafter was negative. The urinary nitrogen was high for the first 25 days. This is in keeping with a high basal metabolism, with destruction of tissues high in protein and with low blood cholesterol. Urinary nitrogen was

30 Gm. on the third day, dropped to 13 Gm. on the eleventh day, rose to 25 Gm. on the fifteenth day and stayed at this figure most of the time, until the twenty-third day. It then dropped gradually to 12 Gm. by the twenty-sixth day, and later dropped to 10 Gm., which is about normal for such a diet. Specific gravity was at all times normal.

Urobilin was found in the urine during the first 12 days, was faintly positive the next two days and then remained negative (Schlessinger test). This urobilinuria may have been hemolytic or hepatogenous in origin; it is consistent with a high icteric index such as was present during the first 18 days. The Smith iodine test for urinary bile was faintly positive on the sixth day, but thereafter was negative. Although anuria was anticipated it did not occur. Fluid intake was kept high to combat anuria. Adrenal cortex hormone was also given for this purpose.

COMMENT.—It will be noted first of all that there was an early concentration of red blood cells due, undoubtedly, to the large loss of plasma through the burned area. This effect has been described by Underhill,<sup>4</sup> *et al.*, Beard and Blalock,<sup>5</sup> McIver,<sup>6</sup> Harkins,<sup>7</sup> and others. Of particular interest in this case, is the evidence of additional and tremendous loss of protein as shown by the high nitrogen excretion in the urine. This is often referred to as "toxic" destruction of protein; it has long been observed in typhoid fever and other severe infections and is mentioned by Einhauser<sup>2</sup> as occurring in burns. It also occurs in severe hyperthyroidism; the chemical findings in the present case, particularly the low blood cholesterol, suggested hyperthyroidism even though no basal metabolic rate was obtained. The nitrogen excretion was so high that it was impossible to bring the patient in nitrogen-balance even though a high caloric, high protein diet was ingested. During the first nine days, the negative nitrogen-balance added up to 120 Gm., during the next nine days, it fell to 80 Gm. owing to an increase in the protein intake, during the next nine days, it fell further to 20 Gm. with a further increase in the protein intake. Although this certainly suggests the importance of a high protein diet, the better balance in the last periods may also have been due to an improvement in the clinical condition of the patient. The total nitrogen deficit was, of course, much greater than the figures indicate because fecal nitrogen and loss of nitrogen through the burned areas were not included. In this patient, the feces were not collected but were probably not significantly large; the loss of plasma protein through the burned area on the other hand, though difficult to measure directly, was undoubtedly large. Although toxic destruction of protein is usually attributed to fever *per se* there was only moderate hyperpyrexia in this patient.

A second observation of interest, was the high nonprotein nitrogen of the blood; this, with hypertension and other clinical evidence of uremia, while they point to a derangement of the kidney, could scarcely be attributed to renal insufficiency in view of the large output of normal urine. Indeed, during the most acute days of "pseudo-uremia" the high point of urine output (8,000 cc.) was reached. Could the uremic signs have been due to hepatic insufficiency? Were they manifestations of the "toxic" destruction of protein?

A third point of interest was the jaundice and urobilinuria during the first days of illness. Although this may have been a manifestation of hemolysis (fall of red blood count) the existence of hepatic insufficiency cannot be ex-

cluded. Certainly, there was no hemoglobinuria, and, although the stools were not studied, no alteration in their pigment content was observed grossly. While sulfanilamide was given the maximum dose was small (4 Gm. per day); such manifestations have nevertheless been described as occurring after the ingestion of this drug. In this case, however, the jaundice appeared almost simultaneously with the first dose of the drug and disappeared while it was still being given (see Chart 1).

## CONCLUSIONS

Metabolic and chemical data are presented in the case of a severe burn, which indicate, among other findings: First, a tremendous destruction of protein, as shown by the high urinary output of nitrogen; second, uremic manifestations without evidence of renal insufficiency; and third, a bile pigment disturbance, presumably hepatogenous or hemolytic in origin. The importance of a high protein intake in the treatment of burns is emphasized, not only to replace loss of plasma protein *per se*, but also to cover the tremendous loss of nitrogen in the urine.

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## SODIUM MORRHUATE REACTIONS

REPORT OF TWO SEVERE REACTIONS DURING THE INJECTION TREATMENT  
OF VARICOSE VEINS

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THE SAFETY and effectiveness of the injection treatment of varicose veins has been definitely established during the past 12 years. A number of sclerosing solutions have been found to be fairly satisfactory but the search for an ideal one continues. Such an ideal solution should be one in which the constituents are pure and may be standardized. It should be painless, nontoxic, producing a prompt and firm thrombus, and not producing a slough when injected outside the vein.

The first note on the preparation of sodium morrhuate was by Rogers,<sup>1</sup> in 1919. In 1926, Cutting<sup>2</sup> gave the physical properties of the solution and described the technic of its preparation in more detail. Rogers<sup>3</sup> stated, in 1930, that, in 1918, he had noted the sclerosing action of sodium morrhuate upon veins. But Kittel,<sup>4</sup> in 1930, stated he had noted the effect of sodium morrhuate upon veins and had first suggested its possibilities as a sclerosing agent in the treatment of varicose veins.

From 1930 to 1933, numerous articles appeared extolling the effectiveness and safety of sodium morrhuate in the treatment of varicose veins. Levi,<sup>5</sup> in 1930, stated that in 4,000 injections he had observed no general toxic symptoms. In 1932, Kilbourne, Dodson and Zeiler<sup>6</sup> concluded that sodium morrhuate was not a toxic solution. Also in 1932, Tunick and Nach<sup>7</sup> stated that: In their experience sodium morrhuate was the closest approach to the ideal solution, and that they had observed no systemic or toxic symptoms from its use. F. L. Smith,<sup>8</sup> in 1932, stated that sodium morrhuate was first used in this country at the Mayo Clinic in October, 1930. In an experience of 4,000 injections he had found that the solution produced no general systemic reactions and that it had become his solution of choice.

In 1933, Cooper<sup>9</sup> stated that in 4,000 injections in 600 patients he had found sodium morrhuate to be nontoxic and that it met all the requirements for a safe and effective sclerosing agent. Also in 1933, Ochsner<sup>10</sup> concluded that sodium morrhuate was not toxic and was the most efficient sclerosing agent.

In 1933, two reports appeared which were at variance with the generally reported opinion regarding sodium morrhuate: Haines<sup>11</sup> found there was a great variation in the composition and purity of various commercial samples

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of sodium morrhuate. Then, in November, 1933, Biegeleisen<sup>12</sup> reported his experiences with various sclerosing solutions. He concluded that sodium morrhuate was an unknown, relatively unstable mixture of sodium salts of unsaturated acids found in cod liver oil and that its potency diminished with age and was not uniform.

In 1934, Zimmerman<sup>13</sup> reported the first serious allergic-like reaction to sodium morrhuate, listing four cases. In 1935, Praver and Becker<sup>14</sup> reported cutaneous eruptions or nitritoid crises in seven out of 176 patients who had received 783 injections. Lewis,<sup>15</sup> in 1936, reported a severe systemic reaction following the injection of sodium morrhuate. He stated his colleagues had had three similar cases. All four cases had had injections of sodium morrhuate at a previous interval of one year or more. In February, 1937, Dale<sup>16</sup> reported a severe reaction with vascular collapse. His case reacted differently from previously described reactions in that there was no cessation in treatment prior to the reaction.

In August, 1937, Hatcher and Long<sup>17</sup> reported a reaction to sodium morrhuate in which there was not only a severe general reaction but also a transient paralysis of one arm. Traub and Swarts,<sup>18</sup> in September, 1937, reported two cases, in detail, of anaphylactic reactions to sodium morrhuate. They mentioned they had had a third case and that Dr. A. Wilbur Duryee had seen three similar cases. In each of these cases there was a "rest period" of from four months to three years between courses of injections. In November, 1937, McCastor and McCastor<sup>19</sup> reported two reactions, one occurring in a varicose vein injection and one from injection of sodium morrhuate into an hydrocele. Simmons,<sup>20</sup> in March, 1938, reported two general reactions from the use of sodium morrhuate in internal hemorrhoids. The reactions occurred on the second injection after an interval of one week.

*Discussion.*—The mechanism of the reactions is still obscure. It was suggested by Zimmerman<sup>13</sup> that the reactions may result from liver proteins in the sodium morrhuate or from the saponified fatty acids themselves. Praver and Becker<sup>14</sup> analyzed the protein content of sodium morrhuate samples and concluded that "the protein content is not sufficient in itself to produce sensitization but the sodium morrhuate may act as a haptene and sensitize susceptible individuals." However, Lewis<sup>15</sup> concluded that the reactions were due to some protein liver radical in the sodium morrhuate solution to which certain individuals become sensitized and in whom later injections with the same solution caused foreign protein reactions. Dale<sup>16</sup> felt that the reactions were not anaphylactic, due to some liver protein as suggested by Lewis, but rather a specific reaction due to an idiosyncrasy to the sodium morrhuate.

Simmons<sup>20</sup> stated that another theory which has been offered is that hemolysis may occur, the contact of the patient's blood with the solution resulting in the liberation of protein substances which are responsible for the reaction.

A study of the reported cases shows that most of the very severe gen-

eralized reactions occurred on the first or second injection following a "rest period" of from several months to three years after the first course of injections. Also many of the cases had slight reactions in earlier injections, which were only noted when viewed in retrospect and the severe reaction could have been prevented by avoiding further injections of sodium morrhuate. The reported reactions occurred from the preparations of various pharmaceutical houses, so it seems reasonable to rule out any impurity or contamination arising from the manufacture of the solutions.

In the Varicose Vein Clinic of the Stanford University Medical School, more than 4,000 injections of sodium morrhuate have been given and two severe reactions have been noted. Except for these reactions, we have found sodium morrhuate to be a safe and effective solution for the treatment of varicose veins. There have been but four sloughs from the use of the solution, and no pulmonary complications.

Following are the case reports of two severe reactions following the injection of 5 per cent sodium morrhuate in the treatment of varicose veins:

**Case 1.**—C. E., male, age 63, was first seen, June 3, 1933, for a varicose ulcer of the left leg and severe varicosities of both legs. A high ligation of both saphenous veins was performed, and this was followed by several injections of 20 per cent sodium chloride. He returned to the Clinic, June 11, 1934, 11 months later, with a varicose ulcer of the right calf. He received seven injections of 2 cc. of 5 per cent sodium morrhuate at intervals of from one to two weeks. Before the treatments were completed he again disappeared for 11 months. He returned in September, 1935, with a small ulcer on the right leg. He received two injections of 2 cc. of sodium morrhuate each on two occasions, and then failed to report to the Clinic for eight months. On July 2, 1936, he returned for a continuation of his treatment and was given 2 cc. of sodium morrhuate with no reaction. One week later he was again given two injections of 2 cc. of sodium morrhuate.

Immediately after the second injection the patient broke out in a cold sweat. He felt ill and stated he had pain in the pit of his stomach. A short time later he began having tingling and burning of the palms of his hands. An urticarial rash appeared on the volar surface of his forearms. Blood pressure 160/100. Pulse 100. Gradually, within 15 minutes, the symptoms subsided. Epinephrine was not administered because by the time the rash appeared he was beginning to feel better. The patient was able to go home after resting an hour.

He was seen one week later. The ulcer had healed. There were no general symptoms. Two weeks after the reaction, he returned and was seen by another physician who did not read the patient's history carefully and thought that the reaction described referred to a local reaction which had subsided, so he injected 2 cc. of sodium morrhuate. Five minutes following the injection the patient coughed, wheezed and drooled at the mouth. His pulse became very weak and extremely rapid. He rapidly became cyanotic and then lost consciousness. The blood pressure fell to 50/40. His face and tongue became swollen. The respirations were extremely stertorous and then spontaneous breathing ceased for several minutes. The air passages were opened by pulling the tongue forward with a clamp and artificial respiration was started. Oxygen was administered through a nasal catheter and he was given 1 cc. of 1:1,000 epinephrine and 7½ gr. of caffeine sodium benzoate hypodermically. After five minutes, spontaneous respiration was resumed and it was possible to stop the artificial respiration. Within 20 minutes the color had improved, his blood pressure had risen to 80/60 and pulse slowed to 100. He was given an additional 0.5 cc. of epinephrine. His condition continued to improve and he regained consciousness in about a half hour. Fifteen minutes after the onset of the reaction, he

began to cough up pink-tinged frothy fluid and this continued in decreasing amounts for one hour. After two hours of rest in the Clinic it was possible to move him into the hospital where he was kept for two days.

On admission to the ward his temperature was 38° C., pulse 120, blood pressure 120/60. Within a short time, the blood pressure dropped to 80/40 and he again became cyanotic. He was given ephedrine gr.  $\frac{1}{4}$  and the  $7\frac{1}{2}$  gr. of caffeine sodium benzoate was repeated. One hour later, the pressure was up to 110/80 and his general condition was improving. R.B.C. 4,790,000, 90 per cent hemoglobin; W.B.C. 17,000, 82 per cent polymorphonuclears, 17 per cent lymphocytes, 1 per cent monocytes. Blood Wassermann negative. Urine examination negative.

He showed no further signs of shock and was dismissed on the second day. Examinations in the Clinic later failed to show any residual signs or symptoms from the reaction.

**Case 2.**—H. M., male, age 73, was first seen in the Varicose Vein Clinic, November 23, 1931. He had had severe varicose veins for many years. He had had stripping operations of both legs in 1903, and again in 1913. On admission he showed marked varicosities of both legs. During January and February, 1932, he had high ligation of both saphenous veins with injection of the distal ends with 20 per cent sodium chloride. He received two injections of 2 cc. each of sodium morrhuate on three occasions. He returned to the Clinic 18 months later with a recurrence of some of the varicosities. He was treated with a series of injections of 20 per cent sodium chloride. Nine months later, he was treated with sodium morrhuate, making 13 visits at weekly intervals and receiving one to two injections of 2 cc. each on each visit. He had no reactions from the injections. Then he was not seen again in the Clinic for three years. He returned, October 11, 1937, with bilateral recurrences. He was injected with 0.5 cc. of sodium morrhuate and there was no reaction. On October 15, 1937, he was injected with 2 cc. of sodium morrhuate. Some generalized itching of the skin was noted but he did not mention it before the next injection. On October 21, he received another injection of 2 cc. Again, there was pruritis lasting about three hours. Again, he did not mention the itching before the next injection. On October 28, he again had the itching, this time with the development of wheals lasting about three hours. On November 4, he again made no mention of any of the previous reactions, later stating that he did not think the itching amounted to anything. He was given two injections of 2 cc. each of 5 per cent sodium morrhuate. He had no immediate reaction. While leaving the Clinic, about ten minutes after receiving the injections, he felt chilly and began to itch all over. He thought he would try to "walk it off" but the symptoms continued to increase in severity. Within 15 minutes, he felt as though his face were swelling, especially the upper lip. The upper lip was puffed up and felt stiff, his tongue became swollen and a half hour after leaving the Clinic he fainted on the street and believes he was unconscious for several minutes. He was taken into a house, his clothing loosened and he gradually improved so that he was able to continue on to his home after another half hour. For the following four days he stated that he had no appetite. Twenty per cent sodium chloride was used for subsequent injections and a good thrombosis was obtained.

#### CONCLUSIONS

Two additional cases are reported of severe anaphylactoid reactions following the injection of 5 per cent sodium morrhuate.

The two reactions reported here are the only serious complications we have noted in more than 4,000 injections of 5 per cent sodium morrhuate.

Most of the recorded severe reactions have occurred on the first or second injection following a "rest period" of from several months to three years after a course of injections of sodium morrhuate.

There are usually signs and symptoms of increasing sensitivity with succeeding injections, and severe reactions may be prevented by stopping the use of the solution. The patient should be carefully questioned before each injection regarding any reaction to previous injections.

Small doses of not more than 0.5 cc. should be used for several injections on beginning the second and subsequent courses of injections when using sodium morrhuate.

The cause of these rare reactions is still obscure.

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## MASSIVE DOSES OF LUGOL'S SOLUTION IN ACUTE, SECONDARY PAROTITIS

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IN 1929, one of the authors (D. J. L.) began the treatment of acute, secondary parotitis with massive doses of Lugol's solution. In this rare disease, which has a mortality rate of 30 per cent, this treatment has proved most gratifying. We<sup>1</sup> reported the results of our first ten cases in May, 1935. There were no deaths in this series. With the cooperation of other members of the profession, we have, since then, accumulated 13 other cases, which form the subject of the present communication.

In this article, we shall, intentionally, omit any reference to diagnosis and etiology<sup>2, 3</sup> of acute, secondary parotitis. The first is self-evident, and the latter, a controversial subject well discussed elsewhere. We shall direct our attention chiefly to the treatment of this disease with massive doses of Lugol's solution, stressing our results as compared with other forms of treatment.

Symptomatic treatment of acute secondary parotitis over a period of 50 years has had little effect on the mortality rate. The first advancement was made by Rankin and Palmer,<sup>4</sup> who, in 1930, introduced the "Radium Pack Treatment." This treatment could be effectively applied, and properly controlled only by a competent radiologist, and available only to those of means. Thus the radiologist soon turned to roentgenotherapy as a substitute. In this field, Robinson and Spencer<sup>5</sup> were pioneers. Roentgenotherapy appears to be as effective as radium, and to-day is extensively employed in the treatment of this disease. Its administration has reduced the mortality rate to about 20 per cent.

The treatment of parotitis by dilating Stenson's duct, predicated upon the underlying pathology being a duct obstruction, requires some elucidation. Hobbs and Snieirson<sup>6, 7</sup> have written several comprehensive articles on the subject, and presented sialograms as evidence of their contention. In one of their more recent articles, they advocate dilatation of the duct only in cases of ascending infections, and state that dilatation is never indicated in hematogenous infections. In our cases, we were unable to make such a differential diagnosis. We believe that dilating Stenson's duct in any case of acute, fulminating parotitis requires the utmost caution. In cases of frank obstruction, which as a rule are uninfected, dilatation is the treatment; here,

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## LUGOL'S SOLUTION IN PAROTITIS

neither roentgenotherapy nor Lugol's solution is of value. They report a mortality rate of 20 per cent.

The therapeutics of Lugol's in parotitis is not well understood. It may be due to the parotid sensitivity to iodine,<sup>8</sup> and the metabolic changes that occur in the gland during its elimination; or by the direct action of the high concentration of the iodine ion on the bacteria. The glands are indeed very prompt and active in the elimination of iodine. As the iodine is eliminated by the parotids, it is promptly reabsorbed by the intestinal tract, completing cycle after cycle through the glands, until final elimination by the kidneys, which requires from 40 hours to several days. We are inclined to believe that the beneficial effect must lie in this constant concentrated flow of iodine through the parotids, be it antiseptic or metabolic in character.

In parotitis, Lugol's solution is administered orally, by vein and hypodermoclysis. Our average daily dose is 160 minims, 20 minims every three hours day and night. In fulminating cases, an additional one or two drachms of Lugol's solution is given intravenously or subcutaneously, in saline or glucose; one drachm to the 1,000 cc. We continue this daily dosage until the inflamed gland shows definite signs of improvement; then the dose may be gradually decreased, and discontinued when the active process has subsided. We never incise the gland if an abscess forms, but aspirate the pus daily through a large caliber needle. These abscesses, when they occur, are usually multiple and discrete, due to pressure necrosis; thus adequate drainage is seldom accomplished by incision. Incision invites mixed infection which adds to the seriousness of the disease.

### ILLUSTRATIVE CASE REPORTS

**Case 3.**—Miss M. M., age 13, on November 3, 1935, had a ruptured appendix with general peritonitis. She recovered from the acute process in 12 days. On November 27, pain again developed in the abdomen. The appendix was then removed. There were many long "guy-rope" adhesions, and a straw-colored serum in the general peritoneal cavity as evidence of recent general peritonitis. On November 29, a right parotitis developed which became quite severe the following day; temperature 103° F., pulse 120. Lugol's solution, minims 20, was given every three hours, and minims 60 in 1,000 cc. of saline daily by hypodermoclysis. By December 1, there were definite signs of improvement and the Lugol's solution was gradually diminished. The swelling and other signs completely disappeared by December 5. She was discharged the following day. A *Staphylococcus aureus* was cultured from Stenson's duct. Six hundred ten minims was the total amount of Lugol's administered.

**Case 4.**—Mrs. R. C., age 47, suffered with two large cystic ovaries. Her abdomen was the size of a full term pregnancy. On October 8, 1938, a bilateral oophorectomy was performed; each specimen was about 20 cm. in diameter. There were broad vascular bands of adhesions firmly attaching the ovaries to the surrounding structures. The left ovary was so firmly adherent in the pelvis that the fibrous capsule was left *in situ*. Surgery in this case was very extensive. On October 10, a double parotitis developed with a temperature of 105° F., pulse 136, marked cyanosis and shock. She was not expected to recover. Lugol's solution, minims 20, was given every three hours orally, in addition minims 60 in 1,000 cc. glucose intravenously and minims 60 in saline interstitially, daily.

This dosage was continued with some variation as condition arose. An oxygen tent was constantly required for three days. On October 13, the swelling gradually subsided. There was complete recovery from the parotitis on October 14, and the Lugol's solution was discontinued. There was some difficulty with urinary retention and profound weakness for several days following. Total amount of Lugol's solution given was 1,130 minims.

**Case 7.**—Mrs. E. M., age 31, was operated upon, June 21, 1938, for ruptured ectopic pregnancy. The right tube, ovary and appendix were removed. On June 25, a right parotitis developed which became very extensive and painful; temperature 101.4° F., pulse 110. Lugol's solution, minims 25, was given every three hours, and minims 60 in 1,000 cc. of saline interstitially, daily. The auditory canal became occluded by the swelling. On June 28, the gland became very tense, with a shiny redness anterior to the ear. On June 29, an abscess ruptured into the auditory canal. Aspirations were begun on July 1, through a large caliber needle. Recovery was rapid, and the patient was discharged, July 10. The total amount of Lugol's given was 1,320 minims.

**Case 11.**—Mrs. A. C., age 46, was suffering from uterine fibroid and diabetes. On June 30, 1938, after proper preparation, a subtotal hysterectomy was performed. On July 3, a bilateral parotitis developed, most marked on the left side; temperature 104° F., pulse 130. Lugol's solution, minims 25, was given every three hours, and minims 60 in saline daily by hypodermoclysis. The blood sugar rose to 312 Mm. per 100 cc. of blood. The swelling became more pronounced, and on July 5, parenteral Lugol's was increased to 120 minims daily. The glands now began to subside. Because of nausea the oral Lugol's was discontinued and, on July 6, parenteral Lugol's was increased to 180 minims daily. By July 9, the swelling disappeared and the Lugol's was discontinued. On July 10, the temperature suddenly rose to 106° F., and bronchopneumonia developed. She expired three days later. The total amount of Lugol's given was 1,670 minims. A *Staphylococcus aureus* was cultured from the right and the hemolytic streptococcus from the left Stenson's duct.

**Case 12.**—Mr. S. P., age 32, developed a right-sided parotitis on the fifth day after the onset of an upper right lobar pneumonia. The parotid involvement was so marked that the jaws could scarcely be separated; temperature 101.6° F., pulse 100. Lugol's solution, minims 20 every three hours, was given orally and minims 60 in 1,000 cc. of saline by hypodermoclysis. The inflammation went on to suppuration. It was not incised but aspirated through a large caliber needle every third day. The Lugol's solution was discontinued on the eighth day but aspirations were continued until the twentieth day. A pneumococcus was recovered from the pus. The total amount of Lugol's solution employed was 1,615 minims.

It might be well to also mention that 14 cases of epidemic parotitis (mumps) have also been treated with Lugol's solution. These cases responded promptly and all completely recovered, even in bilateral instances, in three to six days.

Thirteen cases of acute parotitis are herewith presented which were treated with massive doses of Lugol's solution. This makes a total of 23 cases reported by us to date. In this series, the largest amount of Lugol's solution was given in Case 11, 1,670 minims; and the smallest amount was in Case 2, 120 minims. The average time required for recovery from the parotitis was about five and one-half days. The longest time was eight days. Two cases suppurated (Cases 7 and 12); both were treated by aspiration through a large caliber needle. In Case 12, the abscess was aspirated every third day, and continued to the twentieth day. We believe that this period would have been shortened by daily aspirations. In this case, the active process had practically subsided on the eighth day, at which time the

## LUGOL'S SOLUTION IN PAROTITIS

SYNOPSIS OF 13 CASES OF ACUTE, SECONDARY PAROTITIS TREATED WITH LUGOL'S SOLUTION

TABLE I

Case	Patient	Operation or Disease	Age	Onset	Side	Temp.	Organism	Lugol's	Duration
1	Mrs. W. E. No. 57069	Pelvic peritonitis	25	8th day	L.	103.6°	<i>Staph. aureus</i>	Minims 20 q. 3 h. Minims 60 by hypodermoclysis, daily for 3 days (total 1,040 minims)	8 days
2	Mrs. H. S. No. 53517	Choledochostomy	31	5th day	R. and L.	101.8°	<i>Staph. albus</i>	Minims 20 q. 3 h. (total 120 minims)	3 days
3	Miss M. M.	Appendectomy	13	2nd day	R.	101.3°	<i>Staph. aureus</i>	Minims 20 q. 3 h. Minims 60 by hypodermoclysis, daily for 3 days (total 610 minims)	6 days
4	Mrs. R. C. Mrs. M. M. No. 56214	Bilateral oophorectomy Nephrectomy	47	4th day	R. and L.	105.0°	<i>Staph. albus</i>	Minims 20 q. 3 h. (total 830 minims)	6 days
5	Mrs. L. D. No. 1592	Thrombophlebitis	45	10th day	L.	102.0°	<i>Staph. aureus</i>	Minims 20 q. 3 h. (total 180 minims)	3 days
6	Mrs. E. M. No. 62637	Salpingectomy	31	4th day	R.	101.0°	<i>Staph. albus</i>	Minims 20 q. 3 h. (total 400 minims)	3 days
7	Mrs. J. F. No. P 1022	Celiotomy, Bowel obstruction	50	3rd day	L.	101.0°		Minims 25 q. 3 h. Minims 60 by hypodermoclysis, daily for 3 days (total 1,350 minims)	9 days
8	Mrs. V. S. No. 6-2213	Celiotomy, Bowel obstruction	57	3rd day	L.	101.4°		Minims 20 q. 4 h. (total 480 minims)	4 days
9	Mrs. E. R. No. 62686	Influenza Hysterectomy Diabetes mellitus	65	13th day	R.	102.4°	<i>Strep. haemo-</i> <i>lyticus</i> , (R.)	Minims 20 q. 4 h. Minims 60 intravenously, daily for 6 days (total 840 minims)	4 days
10	Mrs. A. C. No. 62328	Lobar pneumonia	46	3rd day	R. and L.	101.0°	<i>Staph. aureus</i> (L.)	Minims 25 q. 3 h. (total 400 minims)	8 days
11							<i>Staph. aureus</i> (R.)	Minims 25 q. 3 h. Minims 60 by hypodermoclysis, for 2 days (total 2,200 minims)	6 days
12	Mrs. S. P. No. 52328		32	5th day	R.	102.0°	<i>Pneumococcus</i>	Minims 20 q. 3 h. Minims 60 by hypodermoclysis, daily for 2 days (total 1,615 minims)	7 days
13	Mr. S. P.	Bronchopneumonia	16	6th day	R. and L.	101.0°	Pneumococcus	Minims 20 q. 3 h. (total 420 minims)	5 days

Lugol's solution was discontinued. In Case 7, rupture of the abscess may have been avoided by earlier aspirations. Spinal anesthesia was given in every operative case except Case 8, which had ether. Nausea from the Lugol's was overcome by decreasing the oral and increasing the parenteral administration. The water balance was carefully maintained in all cases. There were no deaths in either series except Case 11, which developed bronchopneumonia after recovery from the parotitis and died four days later. This case responded well in spite of a concomitant diabetes. Case 4 was not expected to recover; there was marked cyanosis, severe shock, temperature 105° F., pulse 136, at the onset. Within three days, on massive doses of Lugol's and oxygen, the improvement was striking (Table I).

## SUMMARY AND CONCLUSION

- (1) Thirteen cases of acute secondary parotitis, treated with massive doses of Lugol's solution, are herewith reported, making a total of 23 cases treated by us to date.
- (2) There were no deaths. One case which had recovered from the parotitis, developed bronchopneumonia, and died four days later.
- (3) In most cases, pus was easily expressible from Stinson's duct, and the organism was recovered in every case that was cultured.
- (4) The most effective method of treating secondary parotitis is with massive doses of Lugol's solution.

We wish to express our appreciation to Drs. James Blain, Louis Stern, Lionel Braun and Adolph Spiro for permitting us to observe their cases; their excellent cooperation has made this publication possible.

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## BRIEF COMMUNICATIONS AND CASE REPORTS

### RECONSTRUCTION OF A HAND AND FOUR FINGERS BY TRANSPLANTATION OF THE MIDDLE PART OF THE FOOT AND FOUR TOES

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MONACO

AND

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IN 1917, the author<sup>1</sup> published the preliminary report of this case and the immediate result. The patient was subsequently lost sight of until Ranschburg recorded the ultimate result in a neurologic review.

**Case Report.**—M. J., a Hungarian soldier, had had his right hand mutilated by a hand grenade in 1917, so that only the thumb, which was rigid and deeply scarred, and the root of the hand with a very small portion of the metacarpus remained.

**Operative Procedure.**—All scar tissue was excised from the injured hand. The remaining metacarpus were exposed and the extensor tendons liberated. A curved incision was then made over the dorsum of the right foot which penetrated to the sheaths of the tendons which were sectioned one inch proximal to the line of incision (Fig. 1). The tissues were then raised close to the base of the metatarsus. The metatarsus were resected one inch distal to the line of the skin incision. The sections were not made in the same plane, not only to protect the deep sutures, but more particularly to establish a maximum of contact between the tissues of the hand and those of the foot without the lines of contact between nonsimilar tissues being contiguous.

Holding the four toes and the sectioned metatarsus thus mobilized, in the left hand, they were extended plantarwards as far as possible, so that distal segments of the metatarsus and those from the remainder of the foot could be raised and freed some inches from the tissues of the sole of the foot. The portion to be transplanted, which was only pedicled on the side of the sole of the foot, was quite mobile. The hand was now placed in contact with the foot. First, the periosteum of the metatarsus was sutured to that of the metacarpus with catgut. This was difficult to accomplish and, at certain points, the periosteum could be coapted only with the support of the fascia.

The extensor tendons were sutured together with fine silk and a few sutures of fine catgut were employed to unite the sheaths of the tendons with the adjacent tissues. The fascia was sutured with catgut, and bronze-aluminum sutures were placed in the skin.

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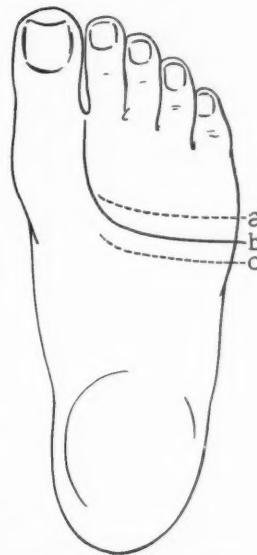


FIG. 1.—Line drawing of the right foot showing (a) the level of section of the metatarsus; (b) the line of the skin incision; and (c) the level of division of the tendons.

It was considered a most important procedure to coapt the ends of corresponding vessels by suturing adjacent tissues about their juncture, in the hope of predisposing to, and facilitating, the formation of collaterals.

A plaster encasement, immobilizing the hand, arm, foot and leg, was applied, leaving the toes exposed. The patient was placed in bed and was well supported on every side.

*Subsequent Course.*—During the first postoperative night, the patient fell out of bed



FIG. 2.—Photograph (20 years postoperative) showing the ultimate result viewed from the dorsal aspect.

and tore out several of the skin sutures; the condition of the deep sutures could not be determined. Notwithstanding this accident, the wound healed quickly and well, partially by granulation.

Four weeks after operation, half the pedicle was cut off close to the fourth and fifth metatarsus, and in the wound thus formed, the tendons of the portion to be transplanted were sutured together separately, the sheath of the tendons and of the tissues to those

of the volar wound of the hand (fourth and fifth fingers). Several skin sutures of silver were introduced.

Five days later, one month after the primary operation, the remainder of the pedicle was severed, and the tendons of the second and third fingers were sutured to those of the corresponding toes. The skin wound was closed. The secondary wound in the foot was treated in the following manner: In order to obtain a good sole for the remainder of the foot, a section of the tissues of the sole was made as far distal as possible, so that the flap of the sole not only covered the entire plantar surface, but could also be sutured over the dorsum of the foot. This procedure, undoubtedly, endangered the viability of the newly transplanted hand, as there remained only a small portion of skin for the hand with which to make an adequate covering for the muscles, nerves and vessels.

The cicatrization had penetrated very deeply, but precautions had been taken that the point of junction of the tendons should not lie directly underneath, nor in contact with, the area of cicatrization in the skin, in order to prevent subsequent immobilization of the tendons.

*Final Result.*—The hand was perfectly capable of holding different objects. Figure 2 shows the general appearance of the transplanted toes 20 years after operation. The remaining big toe of the resected foot was in good condition, and the function of walking was in no way impeded. The foot had retained its four points of support; only the point at the head of the fifth metatarsal had been replaced by one closer to the heel.

PRACTICAL EFFECTS OF THE OPERATION AND THEIR NEUROLOGIC  
EXPLANATION

*The Question of Spontaneous Union of Dislocated Nerves*

PROFESSOR RANSCHBURG

The above reported case, which might well be captioned "The Man with the Foot-Hand," had had the stump of his right hand, with only the thumb left, repaired by means of a transplant of four toes and their corresponding metatarsus from his right foot. This is certainly Doctor Esser's masterpiece of plastic or corrective surgery. I have had the opportunity of examining the patient several times since the operation, at the Neurologic Department of the Hospital of Budapest.

The intention of the surgeon was to create a new hand by quite an original procedure, completing the misshapen and useless stump by a practical, usable instrument which was not only esthetically excellent, but which would also act as a practical motor.

Neither before, nor for weeks after the operation was there any real voluntary motor-like activity of the "toe-fingers." Nevertheless, by the help of the thumb, through adduction, flexion and apposition to the toes, his hand has become quite a useful instrument for grasping, holding and drawing; only the mechanism lacked any information of a sensitive nature, *i.e.*, touch, pain, temperature, localization on the skin and orientation of the movements and position, if not assisted by the help of vision or the sound left hand.

The patient was discharged from the hospital and ordered to return to the Follow-Up Clinic once a year for examination. Meanwhile, Doctor Esser having left Budapest a few months after the operation, I had the opportunity

of repeatedly examining this most interesting case. He was very proud of his ability to use his right hand in dressing and especially in lacing his shoes and unrolling his foot wrappings. He related and demonstrated how he had helped at the harvest in the usual way and generally performed most home and field labors with his "foot-hand" without any difficulty.

A most precise examination showed this eupraxia as being conditioned partly by motor-like, partly by sensitive support. From the motor-like side, there was to be found, besides the perfect use of the thumb in leaning and pressing it tightly against the "toe-fingers," an undoubtedly effective, although purely mechanical flexion of the "toe-fingers." This had been rendered possible by the help of the suture of the tendons, without the help of the short lumbricales and interossei, all of which were, of course, lacking; and also by active adduction of the "toe-fingers," the second on to the third, and the fourth on to the fifth, effective even against resistance, by means of the long extensors of the fingers. Thus, the acquired mobility could not be judged as an effect of a successful suture of the nerves, because the nerves of the long muscles had not been injured, but as a purely mechanical consequence of the perfectly successful orthopedic-surgical intervention.

Of course, this success would have been incomparably less, if the spontaneous juncture of the smashed, degenerated central stumps of the sensitive nerves of both sides of the hand, to the peripheral stumps of the foot, had not been so meticulously accomplished. The complete regeneration was due to the perfect circulation in the transplant.

The epicritical sensitiveness of touch, examined by stroking with a fine paint brush, was present on almost the whole volar and dorsal surfaces of the transplanted "foot-hand." Even a certain primitive localization of touch, generally found in the first stage of the recovery after nerve suture, was present, *i.e.*, each stimulation of the plantovolar skin of one of the toes was correctly signalized, also topically; whereas, dorsal touching of any toe had the coarser effect of being localized more proximally upon the surface of the skin of the corresponding "metatarso-metacarpal" region.

The sensibility to pain was obvious everywhere, and pin-pricks were localized about as correctly, or with the same errors, as those of the touch with the pencil, *i.e.*, they were, in the main, correct. Two simultaneous touches, as well as pin-pricks, were judged correctly as often as falsely, *i.e.*, 50 per cent of them; whereas, the touching of the normal sole of the left foot resulted in 75 per cent correct judgments from a distance of 4.5 Mm. of the point of the esthesiometer. Dorsally, the space amounted to 6 to 7 Mm. stereognosis on, beneath, and between the "toe-fingers," and examined by ring, knife, brush, *etc.*, was stated as zero; whereas, with the toes of the unoperated left foot, it was satisfactorily correct and prompt.

The most striking phenomenon resulted from the examination of the sensibility to temperature. Stimulations by means of test-glasses filled with hot water or with pieces of ice gave correct reactions in 80 per cent of the tests, within three to five seconds. Even when repeatedly examined, the

unoperated left foot amounted to four to five times as many false reactions as the artificial "foot-hand." The explanation of this striking result may be found in the patient's habit of having wrappings around his feet, thus his left foot had been protected since childhood against all changes of temperature; whereas, the right "foot-hand" had been continuously exposed to such weather influences since the operation. Moreover, having been employed as a real hand in the judging of temperature, the "foot-hand" was necessarily put, since the restoration of the nerve conductions, into continual practice.

In a word, the "foot-hand" fulfilled all the ordinary functions of a normal hand, while walking on the remaining part of the right foot was in no way impeded.

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SUTURE OF STAB WOUND OF INFERIOR VENA CAVA

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THE INDICATIONS for operation upon the inferior vena cava are rare. Barnes<sup>1</sup> reports a severe traumatic laceration which necessitated ligation, with recovery. In Sheppe's<sup>10</sup> case, exploration of a gunshot wound of the abdomen revealed a bullet embedded in the anterior wall of the inferior vena cava above the bifurcation. Just as removal was to be attempted, it disappeared. The perforation was successfully closed by suture. The patient died five days later of peritonitis, and the bullet was found in the right ventricle. Wurzel<sup>13</sup> reports a gunshot wound of the inferior vena cava closed by suture, with recovery. Condict<sup>5</sup> reports a case of scissors-perforation of the inferior vena cava, also closed by suture with recovery. The most common injury to the inferior vena cava is a tear or laceration occurring during the course of a right nephrectomy. Many such cases have been reported in the literature.<sup>2, 3, 7, 8, 12</sup> Cole<sup>4</sup> reports a laceration occurring during the removal of an adherent retroperitoneal tumor, which was sutured with recovery. Pfaff<sup>9</sup> reports a similar case in which ligation was performed. If the tear in the vena cava is below the level of the renal veins, it may be ligated with comparative safety. Ligation has also been performed for pelvic sepsis and thrombophlebitis. Wakefield and Mayo<sup>11</sup> report 19 such cases collected from the literature, with four deaths. Walters and Priestly<sup>12</sup> review the surgery of the inferior vena cava, and report four cases of their own in which the inferior vena cava was opened in the course of a right nephrectomy. In two of their cases, it was opened accidentally, and in two others, it was opened intentionally in order to remove a papillary neoplastic

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extension of a hypernephroma protruding from the renal vein. In our case the laceration of the inferior vena cava was the result of a stab wound.

**Case Report.**—The patient, Negro, male, age 41, was admitted to the Receiving Hospital, with lacerations of the chin and arms, and a stab wound in the right anterior axillary line in the eighth intercostal space. He thought these wounds had been inflicted with a pocket knife. *Examination* showed a moderately well nourished and well developed man. The abdomen was rigid. The direction of the wound in the right side

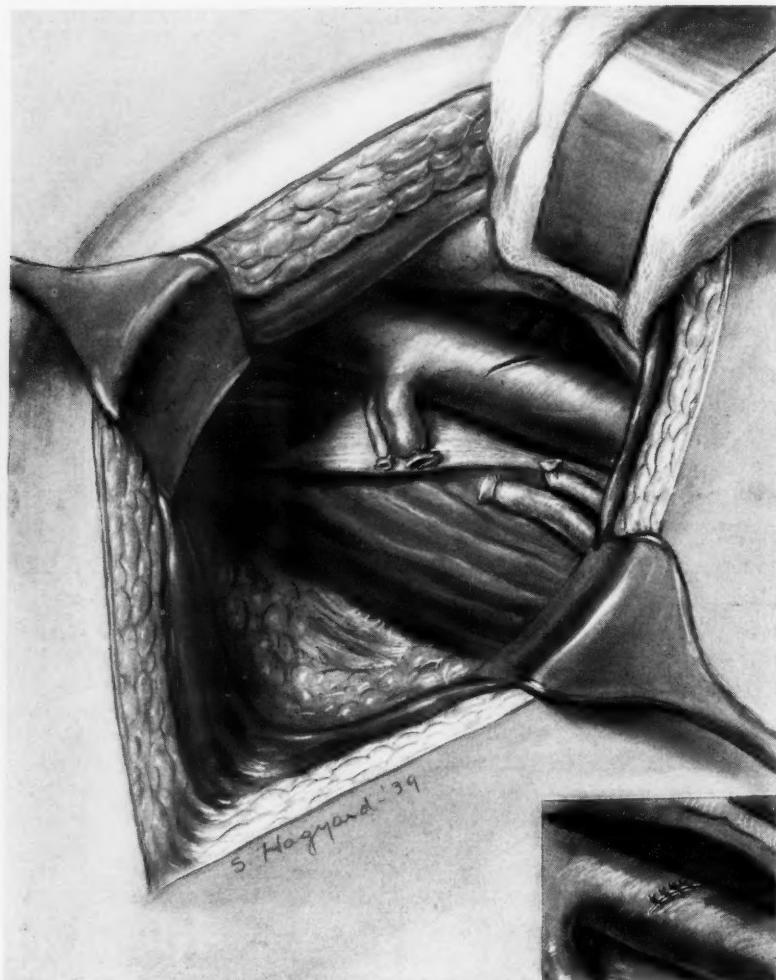


FIG. 1.—The laceration of the anterior surface of the inferior vena cava is shown in the depth of the wound. The kidney has been removed, and the renal artery, vein, ureter and an accessory ureter have been ligated.

appeared to be downward, and as there was a strong possibility that it had penetrated into the abdominal cavity, it was decided to perform an exploratory celiotomy.

**Operation.**—A right subcostal incision was made, and it was seen that the knife had grazed the anterior lateral border of the liver, and passing laterally and posteriorly to the duodenum and hepatic flexure of the colon, had penetrated the posterior parietal peritoneum overlying the upper pole of the right kidney. There was an enormous retroperitoneal hematoma. The rent in the peritoneum was enlarged, and the upper

## WOUND OF VENA CAVA

pole of the right kidney presented. There was a large jagged hole in the kidney which was bleeding profusely. There was also blood coming from about the kidney. Two or three sutures were placed in the kidney in an ineffectual effort to stop the bleeding. As exposure was unsatisfactory, the hole in the posterior peritoneum was closed, and the subcostal incision closed. The patient was then placed on his left side, a transfusion was started, and a right kidney incision was made. A large pool of dark blood was immediately encountered, the kidney being in the center of it. The pedicle was clamped and severed, and several large laparotomy pads were inserted into the depth of the wound in an effort to control the bleeding, and the ureter and vessels were then ligated separately. An accessory ureter was likewise ligated. By this time the pads were saturated with blood. As they were carefully removed, there was a gush of blood from the depth of the wound. This area was compressed between the thumb and forefinger, and as a better exposure was obtained, we discovered the bleeding was coming from a



FIG. 2.

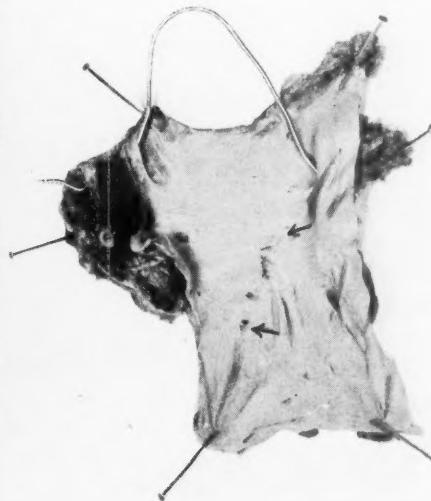


FIG. 3.

FIG. 2.—The patient four months after operation. The arrow points to the scar of the stab wound. FIG. 3.—Gross specimen of the inferior vena cava: The vein has been incised posteriorly so that the anterior wall of the interior surface is visible. The wire probe is seen protruding through the stump of the left renal vein while the other end is inserted into the stump of the ligated right renal vein. The arrows point to either end of the scar on the anterior surface of the vena cava. There is firm healing of the laceration without apparent weakening of the wall of the vena cava. There is a little puckering noticeable about the scar and the silk sutures are visible beneath the intima.

laceration about three-quarters of an inch in length on the anterior wall of the inferior vena cava. This was rapidly closed with five interrupted sutures of fine silk (Fig. 1). Some fat was placed over it and the wound closed. The lacerations of the face and arms were sutured, and the patient was returned to the ward in fair condition.

*Subsequent Course.*—His convalescence, except for a moderate wound infection with some separation which required resuturing, was uneventful. At no time was there evidence of obstruction of the vena cava. He left the hospital on the twenty-sixth day (Fig. 2).

Four months after the operation, he presented himself for treatment for a chronic pulmonary condition which antedated his accident. There was no evidence of obstruction of the vena cava.

The patient was readmitted to the hospital several months after this stab wound had been sutured, suffering from actinomycosis of the right lung. He died six months later. At autopsy, the gross specimen of the inferior vena cava, which contained the site of the sutured stab wound, was removed (Fig. 3).

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## MEMOIR

HARVEY (WILLIAMS\*) CUSHING

1869-1939

FELLOW, AMERICAN SURGICAL ASSOCIATION, 1906-1939

PRESIDENT, AMERICAN SURGICAL ASSOCIATION, 1926

*"To study the phenomena of disease without books is to sail an uncharted sea, while to study books without patients is not to go to sea at all."*

William Osler

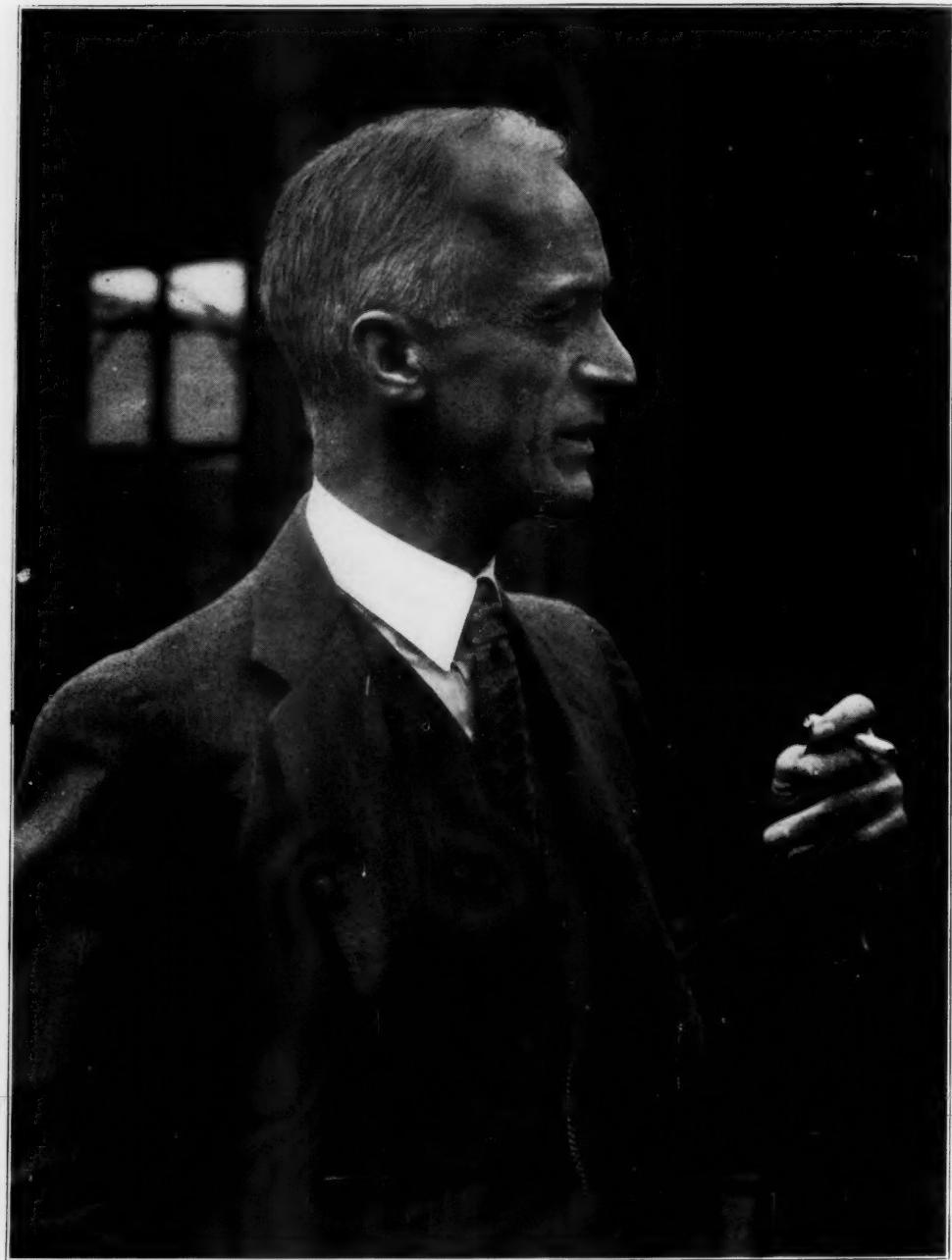
THE DEATH of Harvey Cushing from coronary occlusion at New Haven, Connecticut, October 7, 1939, is of special significance to the Fellows of the American Surgical Association. Among the members of this group he counted his chief friends and from the time he became a Fellow until his death, he was a regular attendant at the Association's meetings as well as a frequent contributor of scientific articles. He liked the informal contacts which form such a valuable part of the meetings of the Association. On these occasions he often tried out, usually quite unheralded to his friends, new ideas which had occurred to him concerning either scientific problems or educational matters. He was keenly interested in the progress of his pupils as they joined the Association and was apt to single out these young men to congratulate them or to show an interest in their work whenever he had the opportunity. We who saw him thus intimately and came to know him better than did others, except perhaps his pupils and immediate associates, recognized his great abilities and the stimulus which his qualities gave to the Fellows of this Association. Fully conscious of his tremendous energy and restless disposition, we saw him reach for and attain achievement after achievement, only to marvel that long before one ambition was accomplished another and greater undertaking was already on its way. We are happy to inscribe here our deep admiration for his great qualities which led him to decorate the American surgery of his time. Although he was widely acclaimed as a superb surgeon, a scientific investigator, a great writer, and a medical historian, we, his intimates, benefited equally from the example he set in the care of sick people. He is no longer with us,

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\* The Williams, his maternal ancestor's name, was finally dropped after his settling in Boston in 1912, where his mail often became confused with that of a surgical colleague, Dr. Hayward Warren Cushing. But an even earlier episode had warned him of this difficulty, for, in 1895, when he had taken the examination for house-pupil at the Massachusetts General Hospital, he failed to hear the result for a long time after the other candidates had been notified. Investigation revealed that his notice of successful application, which seemed all-important to him at that time, had been forwarded to the same Dr. Hayward Warren Cushing, one of the most promising younger surgeons of Boston. This first incident was probably a major influence in his dropping the use of his middle name in his publications as early as 1900.

HARVEY (WILLIAMS) CUSHING

Annals of Surgery  
April, 1940



*Harvey Cushing*

but these qualities will surely be passed on as a part of the tradition of American surgery, and thus his influence will ameliorate the suffering of the sick in the generations to come.

Born in Cleveland, Ohio, April 8, 1869, of a long line of distinguished doctor folk, he came from a typical New England family. His first American ancestor, Matthew, landed in Hingham, Massachusetts, in 1638. Many of his external and spiritual characteristics revealed a stern New England background. He appeared as a reserved individual, holding himself, as a rule, aloof from others in a great crowd, though unbending genially in the company of his friends. The austere and aristocratic portions of his disposition mirror many of our most distinguished American people, who came from the same Puritanic stock. The ancestors of such people were firm in their personal convictions, and stiffnecked and stubborn enough to venture into an unknown country and face great dangers rather than give in to the desires of others. But the Puritans had many attributes, and just as they appeared austere, so in their intimate contacts they often let themselves go and became the warmest of friends. Thus, when they can be approached, hidden qualities of geniality and friendship are displayed which frequently outshine characteristics carried by others more openly on their sleeves. Of such a mixture was Harvey Cushing—apparently stern, a severe taskmaster, more critical of himself than of others, and yet on occasions imbued with a warmth and geniality that astonished all but those who knew him intimately. We who had this privilege are grateful that such an ardent and busy nature should vouchsafe to us the preservation of his friendship.

Following his preliminary education in Cleveland, Ohio, he went to Yale College, where his prowess as a baseball player led him to make his Letter and later to become captain of the team. From Yale College he went to Harvard Medical School, where he graduated with the degrees M.D., *cum laude*, and M.A., in 1895. A review of his grades at the Harvard Medical School is of some interest, for the C minus in Clinical Surgery is in sharp contrast to the eleven A's and three B's. To understand this, one must realize that there was little opportunity for the students of that day to come into close contact with patients in their routine teaching exercises. To obviate this, many students neglected the regular course and spent their time as assistants or "strikers" in hospitals, thereby incurring the displeasure of the teacher thus neglected. At least such action expressed early the independence of Harvey Cushing's mind.

From the Harvard Medical School he went to the Massachusetts General Hospital as house officer on the Surgical Service. Here his industry and his beautiful records, illustrated by his own drawings, set him aside as an unusual person. Here he became interested in the early roentgenographic machine, then just beginning to be used in cases of broken bones. And here he and Amory Codman kept records on special charts, drawn by Cushing, of the progress of patients during anesthesia, records which are to-day looked upon as one of the earliest attempts to set down in visual form the progress of a patient during a surgical operation. Later on, when he had brought back from Italy

a blood pressure apparatus with an inflatable armlet, there really commenced the first intelligent anesthesia charts which have been such an important addition to careful surgery. During his house officership at the Massachusetts General Hospital, he wrote a letter to his friend, W. S. Thayer, then working in the Johns Hopkins Hospital, asking him if by any chance there would be an opening available under Osler, when he was through his service in Boston. This letter to Thayer was never answered, and had it received favorable reception, one simply cannot visualize the difference it might have made in Cushing's career. It would be an interesting matter, indeed, to circularize the American Surgical Association to see what answer our Fellows would have to this problem! Could a man of Harvey Cushing's make-up have been content with medical practice? Would he have found, possibly in the field of neurology, an interest sufficient to absorb all his energy? Would any career in medicine have had a practical enough appeal to a man who found a chief interest in keeping the mortality score of his work and who loved to do physical battle in the accomplishment of his surgical practice?

From Boston he went to Baltimore as assistant on the staff of William Stewart Halsted. Many of you have heard Doctor Cushing himself tell the story of his transition, but since the impact of Halsted's teaching is one of the turning points in his career and indeed one of the few instances where another's influence helped so obviously in charting the future course of his career, it may not be amiss to review the matter. The shift from the Boston surgery of that day, where speed of operating was still considered advisable and even used as a gauge of ability, to the painstaking, slow, and gentle methods of Halsted was an everlasting inspiration to the pupil Cushing. He often told the story himself that, coming from Boston where a complete breast procedure was accomplished in 28 minutes, he saw with misgivings a four and one-half-hour operation for the same undertaking. How amazed he was that stimulants were unnecessary, and how horrified he was when told not to dress the wound for ten days! Recalling the wounds he had previously studied, he remarked to himself, "I may not see the wound, but I shall smell it!" When in ten days the wound was dressed and found perfectly healed, his skepticism disappeared. Moreover, here he was first introduced to the experimental method, and was taught the value of careful and detailed records whether in the laboratory or on the ward. From Halsted he learned that precise and thorough concentration on a small problem might yield more than great labors in routine work. Here, too, he learned the value of a meticulous and gentle technic that sought to spare each cell from being damaged, a technic which was to permit him in the years to come to create the surgery of the central nervous system. It is doubtful if Halsted had any other pupil who learned so rapidly and thoroughly the art of surgery as he, Halsted, conceived it.

Finally, his training as a general surgeon completed, Doctor Cushing went abroad (1900-1901), and in Berne, through Kocher and Hugo Kronecker, accomplished his first work in experimental neurology (*Physiologische und*

anatomische Beobachtungen über einige hiermit verwandte Erscheinungen. Mitt. a. d. Grenzgeb. d. Med. u. Chir., 9, 773-808, 1902). This neurologic field was to become his life work, and it is of interest to examine the stimulus which brought him to it. My notes made after conversations with Doctor Cushing led me to feel that Doctor Halsted suggested to him the field of neurologic surgery, but recently Dr. Roy D. McClure, who worked with Doctor Cushing during the first year that the Hunterian Laboratory was open and who became later Halsted's Resident Surgeon, and others have made it certain that Harvey Cushing himself proposed the field to Doctor Halsted. Doctor Halsted's first reply was, "Why Doctor Cushing, we had only two cases of brain tumor last year!" When Doctor Cushing persisted, Doctor Halsted remarked, "All right, the field is yours." And perhaps there were indications of this leaning even earlier, for the title of Doctor Cushing's second paper was "Haematomyelia from Gunshot Wounds of the Spine. A Report of Two Cases, with Recovery Following Symptoms of Hemilesion of the Cord" (Am. Jour. Med. Sci., 115, 654-683, June, 1898). This article was spoken of by Doctor Thomas, then Professor of Neurology at the Johns Hopkins Medical School, as the best investigation of superficial sensory supply carried out up to that time.

During his first trip to Europe, Harvey Cushing picked up in Pavia, Italy, a clinical model of Riva-Rocci's blood pressure apparatus with an inflatable armlet, which he adopted for use in all his subsequent surgical procedures. This is of special interest, for this apparatus led to a cementing of the friendship between Cushing and George Crile and thus, indirectly, to the founding of the Society of Clinical Surgery, a traveling clinical club in which these two were among the motivating spirits.

On his return from Europe, Cushing became the Neurosurgeon of the Johns Hopkins Hospital group. It was a difficult and discouraging beginning. The mortality was terrific, though better than that obtained by other surgeons. Always there was extreme diligence and thoroughness. Autopsies were secured whenever possible. The reasons for catastrophes were thus explained and technical perfection thus secured. The happier field of the surgical treatment of trigeminal neuralgia was reopened, studied, and made safe. Laboratory efforts previously in the field of general surgery continued in this newer field and soon he began to investigate the pituitary body. Tumors of it were noticed; studies of its functions grew apace; and by the time of his removal to Boston, his first book appeared, "The Pituitary Body and Its Disorders."

During these formative years in Baltimore, when his work hardened entirely along neurophysiologic lines, he discovered in William Osler a chief stimulus and mentor. They were next-door neighbors, and his footsteps were often turned to Osler's home where he found encouragement, guidance, and leaven which only such a brilliant character could give. Here he began to acquire his love of books and his amazing information of the background of medical history. Here he gathered in acquaintances from many corners of the

world to emerge a real cosmopolitan. Osler's departure to Oxford, in 1905, seemed a great loss to Harvey Cushing, but by this time he was well started in his bibliophilic adventures and perhaps was really benefited by the independence of thought and action which this separation enforced. Anyway, the trail between these two was now well established, and their correspondence formed a major tie of interest for each until Osler died.

It will be of some interest for you to know that as early as 1910 Harvey Cushing was appointed Professor of Surgery at the Harvard Medical School and Surgeon-in-Chief at the Peter Bent Brigham Hospital. The new Harvard Medical School was occupied in 1906, and some wise heads had influenced the Board of Trustees, under the will of Peter Bent Brigham, to build an hospital on the cow pasture adjoining this new school. Cushing never taught under this title because, by the time he moved to Boston, in 1912, Maurice Richardson had died, and his title was changed to Moseley Professor of Surgery. In January, 1913, the new Peter Bent Brigham Hospital opened its doors and his labors in Boston began in earnest. The details of his accomplishments in Boston are available to all in the Annual Reports of the Hospital. It is appropriate to point out here that Harvey Cushing and his colleague, Henry Christian, put great emphasis on the value of professional hospital reports. Here they reviewed and prophesied the changing character of both medical education and medical practice, and thus elevated hospital reports to a useful professional level.

At first he kept his interest in the general surgical clinic, but his prominence in neurosurgery was so outstanding that gradually this field occupied all his energy and time. Yet, in spite of these responsibilities, there was at first time for tennis and frequent discussions with the devoted members of his house staff. Indeed, it was these informal meetings, plus his weekly rounds on patients with other than neurologic disorders, and the influence of his great example in the care of his own neurologic patients which permitted him to be the major influence, for many years to come, on many pupils whose interest lay in the field of general surgery. And from time to time he did take on the performance of some unusual task in the field of general surgery, and such procedures will long be remembered by the interns of the first few years of the Brigham Hospital as among their greatest moments of inspiration. Before the Great War was upon us, he had become one of the leading surgeons of our day, a matter attested to by the invitation to give the oration in Surgery at the International Congress of Medicine in London in 1913, "Realignments in Greater Medicine; Their Effect upon Surgery and the Influence of Surgery upon Them" (*Brit. Med. Jour.*, **2**, 290-297, August 9, 1913. Also: *Lancet*, **2**, 369-375, August 9, 1913).

Then came the war, and for Doctor Cushing two experiences, one with the French Army at the American Ambulance Hospital in Paris, April, 1915.\*

\* At the outbreak of the European War, Americans in Paris organized the American Ambulance Hospital under the auspices of the American Hospital, a small incorporated hospital largely used by the American colony there. The French Government placed the new Lycée Pasteur in Neuilly at the disposal of this new Ambulance Hospital. One of

and later, after the United States had entered the war, with Base Hospital No. 5 in France, May, 1917 to May, 1919. His great abilities soon led to his removal from this Base Hospital group, of which he was the organizer and peace-time Director, to become the senior consultant in neurosurgery of the American Expeditionary Force. During these experiences his tremendous labors under the severe physical strain of forward conditions brought comfort and life to many an injured soldier, but his unsparing devotion to the task eventually undermined his health and left him a sufferer from arterial disease for the remainder of his life. All through this period of immense physical strain, his publications continued. His contributions to the care of intracranial war wounds set the proper methods in this field. Great as was his devotion to professional work, he found time to keep up his daily Journal, a habit begun in youth and continued throughout his life whenever he traveled away from home. In 1936, excerpts from his daily War Journal appeared in book form, *From a Surgeon's Journal* (Boston, Little, Brown, and Company, 1936). For his great works in France he was honored by his own country by the award of a Distinguished Service Medal, by Great Britain by the Order of the Companion of the Bath, and by France with the position, Officer of the Legion of Honor.

During this war experience there were several trips to England, and each time the long desired visits with Osler. On one of these occasions the writer was present and recalls as brightly as if it were but yesterday the witty and brilliant chaffing which flowed forth at the time. It was shortly before Revere Osler's death, and though the imminence of disaster seemed in the very air, the comfort and happiness of the guests was overwhelming. Conversation drifted from the first written medical document, a piece of stone covered with unknown writing this time, to how difficult it was for the British to learn the value of corn as food for man, having for centuries thought it fit only for pigs and chickens! All the time Harvey Cushing sat wrapped in devoted and appreciative silence.

After the war he became reestablished in Boston and his labors in neurosurgery took on their final form. His interest in general surgery lagged, for there was no time for it. Assistants flocked to his side to work in neurology and neurosurgery, and the output of their work and influence is worldwide. In the midst of all this William Osler died, and, at the request of Lady Osler, Cushing took up the writing of a biography. It was a labor of love, but it was accomplished with the same tools and vigor that surrounded all Harvey Cushing's works. First every possible source of information was gathered in and digested, the smallest references in daily newspapers were consulted,

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the three services was organized to be staffed by groups which rotated every three months from American Medical School hospitals. A unit under Dr. George Crile, from the Lakeside Hospital, Cleveland, Ohio, began this service January 1, 1915; the Harvard Medical School unit followed, April-June, 1915, and was in turn followed by a unit from the University of Pennsylvania Medical School. Doctor Cushing remained with his unit only for the month of April, 1915, returning via England where he visited Sir William Osler.

and from this background the great two-volume biography appeared. Small wonder to those who knew of the sincere efforts that the product would be so universally acclaimed.

On the occasion of his sixtieth birthday, 1929, his pupils dedicated to him a collection of their writings. This "Festschrift," a special number in honor of Harvey Cushing's sixtieth birthday (Arch. Surg., 18, 935-2045, 1929), emphasized his qualities as a teacher. The 82 papers were contributed by men then holding some of the most important medical and surgical positions not only in the United States of America but in Europe. And the contributions not only were in the field of neurology and neurologic surgery but ranged over the entire field of medicine, and included historical essays as well as experimental and clinical observations. The impact of Cushing's character and abilities is nowhere better pictured than in this affectionate tribute.

His effect upon the Harvard Medical School Faculty was considerable, even though he and the Dean of the School during this period did not always agree in matters of policy and action. Cushing was greatly interested in the establishment of a common library, in the modification of the curriculum with its resultant reduction in didactic hours, and was a leader in opposing the adoption of the "full-time clinical teaching" in the strict Rockefellerian sense, and in opposing a plan that the Medical School edit a text-book which purposed to infiltrate all departments of the School with preventive medicine.

The hospital regulation set by himself and Henry Christian automatically retires the professional members of the Brigham Hospital staff at the age of 63, and this, by custom, is accompanied by resignation from the Medical School appointment. And so, in 1932, arrived the date of retirement set by himself. It came at a time when Doctor Cushing was working as never before, though bothered with peripheral vascular disease and the signs and symptoms of gastric ulcer. The transition from his tremendously active life was great, but he made it abruptly, and surgery was given up. He refused the repeated requests of the Brigham Hospital Trustees to remain in service as Surgeon-in-Chief, and attempts were soon made to entice him to many places, though it was hoped he would stay in Boston and work on his collection of brain tumors. He remained at the hospital for another year, however, and worked in uncomfortable quarters, for he insisted that his successor occupy immediately the quarters set aside for the Surgeon-in-Chief. The following year he went to Yale as the Sterling Professor of Neurology (1933-1937). Here he was offered an active post, not simply an honorary sinecure, and to a man in the full vigor of his years, this opportunity and his natural devotion to his Alma Mater, which had the vision to utilize his great abilities, turned his footsteps away from Boston and Harvard. With him went his collection of brain tumor specimens and photostatic copies of the patient's records. At Yale he continued a thorough study of this great mass of material, the assembling of which represented such unusual physical efforts. Major fragments of this material had appeared either in book form, as the monograph on the acoustic neurinomata (1917) and the classification of the gliomata with P.

Bailey (1926), or in separate smaller publications, notable among these being his final contribution in the field of pituitary disorders, "basophilism," a clinical syndrome which now bears his name. At Yale, the work continued in spite of frequent physical discomforts. Clinical, experimental, and historical papers continued. But chiefly there was the continued study of his own experiences in the field of brain tumors and always there went on the follow-up and end-result letters and examinations.\* Though the Yale professorship terminated in 1937, the work continued unabated, and he was as active from 1937 up to the time he died as at any time in the last five years. The great volume on the meningiomata did not appear until 1938.

This brief glimpse into the life and works of a man who was a friend to everyone here must leave us somewhat stunned by the breadth and profundity of his accomplishments. We knew him as an individual, endowed with unusual ability, ambition, and artistic temperament. We have seen personally the technical perfection of his surgical art, and we have marveled that, in the brief span of a single existence, he was able to accomplish such a mass of high grade endeavor. His abiding curiosity was one of his outstanding qualities and one which constantly led him to intellectual pursuits, often quite unassociated with his professional career. Such a curiosity certainly played a rôle in his acquisition of a great medical library. Take, for example, a book given to him by a friend or a grateful patient. As soon as he had it, he had to know who had owned it before his hands touched it, then all about the author and all about the printer. If any of these was one who had left his mark in the passage of time, then Cushing would ferret about until he knew a good deal about that particular individual. The same was true about things he noticed when traveling. Doctor Councilman was once trying to explain to me, with the aid of a small pocket lens, the difference between the leaves of the various conifers, and for a whole week Doctor Cushing kept at Councilman until he thoroughly understood the details of this simple study into the works of nature.

To many people he was looked upon as a great teacher, and here indeed lay one of his greatest gifts to posterity, for no master has had a more devoted group of pupils, who so obviously have followed in emulation the footsteps of their master. His exquisite handling of tissues, his perfect care of the patient, his leaving no stone unturned no matter what the effort, were the lodestones which drew young men to him in great numbers. His method of teaching was simple. It was the apprenticeship system, and since Cushing was a man of few words, it was largely a teaching through example. It has often been said that Harvey Cushing was a severe task master. He was when it was necessary, but he certainly never demanded greater labors of his pupils

\* As late as July, 1939, a chromophobe pituitary adenoma patient seen first by Doctor Cushing in February, 1926, turned up at the Brigham Hospital to show the writer a letter from Doctor Cushing, inquiring about his condition, with the request that the writer examine him and send the information to Doctor Cushing. This done, there was the immediate grateful reply, so characteristic of his correspondence with a pupil.

than he set for himself, and it causes us no surprise that such an ardent and serious person was impatient with incompetence and slovenliness. His perfectionist attitude brooked no compacts with mediocrity, and throughout all his relations with his pupils there was always time for wise counsel and friendly advice. The pupils always knew, even without a spoken word, that their interests lay close to his heart.

He is survived by his widow, Katharine Stone Crowell, and four children, Mary, Betsy, Henry, and Barbara. Another son, William, the eldest child, was killed in an automobile accident while a student at Yale College. Mrs. Cushing was not a frequent visitor to the meetings of the American Surgical Association, though she did attend the meeting at Richmond when Harvey Cushing was our President. However, she was known to most of the Fellows of our time, for Harvey Cushing almost always had people home to dinner with him when they visited Boston, and on these occasions Mrs. Cushing was the perfect hostess, always interested in the visitor's point of view, and putting him at rest and in comfort through her simple, direct, and thoughtful nature. Fellows of the American Surgical Association who were at one time pupils of Doctor Cushing came to know Mrs. Cushing intimately, and all of these shall forever feel their indebtedness to her for much help and kindness as they climbed the surgical ladder at the Brigham Hospital. We are happy to record here, at a time when we mourn greatly the loss of our friend, our special affection to her who did so much for many members of this association.

We who have so greatly enjoyed our fellowship with Harvey Cushing and profited by this relationship are happy to acknowledge here our admiration for one whose work will descend through posterity for the benefit of mankind. We, his friends, recognize in many of his attitudes and actions the natural ambition of all people, and though we may see less of the supernatural than others, recognize his unusual accomplishments. Through my long and devoted association with him, I believe that he would like best of all to have said about him that he had followed the highest tradition of our profession—that he never had neglected anything that could bring comfort or benefit to a patient. These attributes made him not only a master surgeon but a chief physician of his time.

ELLIOTT CUTLER.

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